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**Public health, nutrition and agriculture: How can  
burden of disease analyses and health impact  
assessment inform food and agricultural policy in  
Europe?**

**Dr Karen Lock**

**Thesis submitted for the degree of Doctor of  
Philosophy of the University of London**

**2006**

**London School of Hygiene and Tropical Medicine**

## **Abstract**

This thesis aims to understand how public health evidence can be used better to inform the development of food and agriculture policy. It sets out to achieve this by developing and applying two methods that have been advocated for use in evidence-based policy making: health impact assessment (HIA) of agriculture and food policy and calculation of the burden of disease attributable to nutritional risk factors. Neither of the methods had previously been used in this policy context. They were selected as they illustrate two extreme models of evidence-based public health. The first consists of research-based, investigator-led analysis producing generalisable, quantitative estimates. The second involves a more contextual, participatory, inter-sectoral approach to collecting, analysing and applying a broader range of data. The methods have been developed and applied using the fruit and vegetable sector as a case study, with specific reference to policies in the Republic of Slovenia, a country that was, during the course of this work, acceding to the European Union and presented a unique political opportunity. This thesis explores how these different evidence-based public health approaches are likely to inform policy, in the light of what we already know about influences on policy making.

This thesis finds the total worldwide mortality currently attributable to inadequate consumption of fruit and vegetables is estimated to be up to 2.635 million deaths per year. Increasing individual fruit and vegetable consumption to up to 600 g per day (the baseline of choice) could reduce the total worldwide burden of disease by 1.8%, and the burden of disease in Slovenia by 2%. The greatest impact would be on reduction of ischaemic heart disease and ischaemic stroke. However, such descriptive epidemiology is an insufficient basis for policy formulation as the results say nothing about how interventions are likely to reduce a problem. The results of the health impact assessment show that evidence demonstrating priorities for public health action will be different from the type of evidence required for planning, policy implementation or evaluation.

## Acknowledgements

I am indebted to Professor Martin McKee, my supervisor, for inspiring me to explore less travelled avenues of public health. I have benefited not only from his unique knowledge and vast experience but also from the constant support, guidance and encouragement he has given me at all stages of the PhD.

I am grateful to the Medical Research Council for awarding me a Fellowship in Health of the Public Research which enabled me to undertake the PhD. Much of the work that appears in this thesis forms part of two research projects. The global burden of disease research was partly funded by the Department of Health. I would like to thank my colleagues on this project including Dan Altmann, Louise Causer (LSHTM), Majid Ezzati (Harvard School of Public Health), Colin Mathers (WHO), Anthony Rodgers and Stephen Vander Hoorn (University of Auckland) and the numerous people who assisted world wide by supplying sources of dietary intake data. I particularly wish to thank Joceline Pomerleau (LSHTM), with whom I worked closely on this and other projects, for her methodological help and support.

The health impact assessment in Slovenia formed part of a WHO and Slovenian Ministry of Health funded project. I wish to acknowledge the help of my Slovenian colleagues Mojca Gabrijelcic-Blenkus (Institute of Public Health), Jozica Maucec Zakotnik (State Secretary, Ministry of Health), Rok Polonic (Ministry of Health), Ales Kuhar (University of Ljubljana) and Peter Otorepec (Institute of Public Health). I also wish to thank Aileen Robertson (former Nutrition Advisor, WHO Europe), Marco Martuzzi (WHO Europe), Carlos Dora (WHO Geneva) and Paul Wallace (UCL) for their input to the development of the work.

The funders listed above cannot be held responsible for any of the information contained or the views expressed in this thesis.

Finally I would like to thank my parents for their steadfast support of my career development over many years, and Shaun for his inexhaustible understanding, patience and encouragement.



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## Abbreviations and acronyms

<i>BSE</i>	<i>Bovine Spongiform Encephalopathy</i>
<i>CAP</i>	<i>Common Agricultural Policy (of the European Union)</i>
<i>COMECON</i>	<i>Council for Mutual Economic Assistance (Economic Organisation of Communist states 1949-1991)</i>
<i>CRA</i>	<i>Comparative risk assessment</i>
<i>CVD</i>	<i>Cardiovascular disease</i>
<i>DALY</i>	<i>Disability adjusted life year</i>
<i>EU</i>	<i>European Union</i>
<i>FAO</i>	<i>Food and Agriculture Organization of the United Nations</i>
<i>GBD</i>	<i>Global Burden of Disease</i>
<i>HLA</i>	<i>Health impact assessment</i>
<i>NCD</i>	<i>Non Communicable disease</i>
<i>RR</i>	<i>Relative risk</i>
<i>WHO</i>	<i>World Health Organization</i>
<i>YLD</i>	<i>Years lived with disability</i>
<i>YLL</i>	<i>Years of life lost</i>



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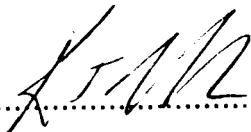
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**PART 1 INTRODUCTION, BACKGROUND, AIMS AND OBJECTIVES**

# **Chapter 1 Food and agriculture as determinants of public health**

## ***Background***

This thesis aims to understand how public health evidence can be used better to inform the development of food and agriculture policy. It sets out to achieve this by applying two methods that have been advocated as tools for evidence-based policy making, assessment of the health impact of agriculture and food policy and calculation of the burden of disease due to nutritional risk factors. It uses the fruit and vegetable sector as a case study to compare and contrast how the two methods can be used in this context.

In this introductory chapter I discuss the background to the thesis. First I outline why research into food policy has been neglected, highlighting the complex nature of the role that food and agriculture policy plays in determining health. Second I review the current burden of diet-related non-communicable (NCD) disease in Europe and examine how much of the burden can be attributed to food-related disease. Third I examine the major links between dietary components and disease, concentrating on the evidence that relates to the health effects of fruit and vegetable consumption. Finally I look upstream at policies on European agricultural production and food distribution, examining their impact on diet and thus on health, asking whether these policies adequately take account of their impact on public health.

## ***The challenges faced by traditional epidemiology in understanding the complexity of food as a health determinant***

A starting point in developing evidence-based public health policies is an understanding of the nature of the relationship between risk factors and health outcomes. There has been an increased understanding of the role of individual risk factors and health over the past four decades. Perhaps the best known example is the pioneering epidemiological research that has demonstrated the clear link between smoking and lung cancer <sup>1</sup>. This research, and other early studies of some of the major determinants of cardiovascular disease, was based on a linear model of disease causation, in which exposure of a susceptible host to an agent led to disease. The exposures that were studied were clearly defined and easy to measure, such as smoking status, blood pressure, or cholesterol level, and the causal pathway was easy to understand <sup>2</sup>. However, the wider application of this approach to understanding the

health of a population faces many problems because of the complexity of much of disease causation. The existence of this complexity is apparent from research showing how individual risk factors often have limited ability to explain the scale of variation of disease in a population. For example in the Whitehall study conventional risk factors explained only a small amount of the observed variation in cardiovascular disease <sup>3</sup>. There are several reasons for this. First, many potential risk factors for disease are difficult to define, let alone measure. For example, in alcohol research the frequency of exposure may be as important as the level of exposure, but is much less easy to quantify <sup>4</sup>. This may also be true of dietary risk factors such as fruit and vegetables whose availability can be seasonal <sup>5</sup>, and the particular components of fruits and vegetables, singly or in combination, have an effect. Second, the single agent medical model of disease has difficulty in addressing situations in which multiple factors interact, such as genetic, environmental, and lifestyle factors. For example, infection with *Helicobacter Pylori* confers a higher risk of stomach cancer, but this is lower in individuals with certain genetic polymorphisms for interleukin-1 (by virtue of its impact on the inflammatory response to infection) <sup>6</sup> and among those with high intakes of dietary antioxidants due to fruit and vegetables <sup>7</sup>. Both the risk factor under study and the potentially interacting factors may be distributed differently among social and ethnic groups within the population. Third, an individual risk factor may be associated with multiple outcomes, some of which may be affected differentially by interacting factors.

Given the scale of this complexity, it should be no surprise that we continue to have difficulty in explaining patterns of population health and in designing appropriate public health interventions.

Assessing the current and future health impacts of food and agriculture policy poses similar problems as with other complex upstream health determinants such as climate change, economic and trade policy. Their impacts are typically indirect and often dependent on local and national context. Exposure is frequently difficult to define and causal pathways are complex. Consequently, it is not surprising that food and agriculture policy, as a complex multifaceted factor in determining health, has until recently received very little attention from public health policymakers. New approaches to food and health are needed that go beyond the traditional relationship of discrete exposure and outcome. These must take account of the complex determinants of

exposure to risk factors, such as the problems people face when making 'healthy' choices, the host response, including the growing evidence of how risk factors interact, and the complexity of any policy response. which may require action by, and may impact on, many different sectors, in ways that are often not obvious.

### ***The burden of diet-related disease in Europe***

This previous neglect of food as an important risk factor is changing. Health policymakers in Europe are increasingly concerned about the growing burden of chronic non-communicable diseases, including cardiovascular disease (CVD), stroke, some types of cancer <sup>8</sup>, with diet and obesity now recognised as major risk factors. Chronic non-communicable diseases are the leading causes of death and disability worldwide and some of the main risk factors, such as obesity, are increasing rapidly in most regions of the world, including Europe <sup>9</sup>. The World Health Report 2003 estimated that cardiovascular disease accounted for 16.7 million (29.2%) of total global deaths, while cancer contributed 7.1 million deaths (12.5% of the total) <sup>10 11</sup>.

Although the precise effects of risk factors for non-communicable diseases are complex, most are at least partially understood and many are modifiable. These include tobacco, alcohol and physical activity. It is increasingly accepted that nutrition is a major modifiable determinant of chronic disease, with scientific evidence supporting the view that alterations in diet have strong effects, both positive and negative, on health throughout life <sup>12-15</sup>.

The Global Burden of Disease study introduced the concept of the disability adjusted life year (DALY) as a summary measure of population health (the approach is discussed in chapter 2). While the first round of the Global Burden of Disease (GBD) study did not look explicitly at the overall impact of nutrition, it provided a conceptual framework that could be used to do so. In Sweden an attempt was later made to estimate the burden of disease that could be attributed to additional risk factors in the European Union (EU) <sup>16</sup>. This study estimated that diet-related factors directly contributed 8.3% of the number of DALYs lost, almost half of this being attributed to low fruit and vegetable intake (3.5% attributable to low fruit and vegetable intake, 3.7% to overweight and 1.1% to high saturated fat intake). In comparison, tobacco smoking accounted for 9% of the burden of disease in the EU. This study suggests that improving diet could be as important as reducing smoking in tackling the disease

burden in Europe. However, these figures may actually underestimate the importance of nutrition as the study did not take account of potential interactions, and it is clear that dietary factors interact with other risk factors. For example, high intake of fruits and vegetables appears to reduce the risk of lung cancer among smokers <sup>17</sup>, although of course smoking greatly increases the probability of developing lung cancer even among those with the highest intakes of fruit and vegetables.

This research, comparing the burden of disease due to different risk factors, can now be seen as an early step in the process of greater recognition of both the public health importance of diet in general, and specifically the health benefits of fruit and vegetable consumption. Another study reported that 23,000 premature deaths (before the age of 65) from CVD and major cancers could be prevented in the EU if fruit and vegetable consumption was increased to recommended levels <sup>18</sup>. These findings are similar to those of more recent studies from New Zealand and Australia <sup>19, 20, 21</sup>. In these countries, it was estimated that up to 3% (2.4% in New Zealand and 2.8% in Australia) of the burden of disease could be attributed to low fruit and vegetable consumption. The Australian study also suggested that approximately 10% of all cancers could be due to an insufficient intake of fruit and vegetables.

### ***Contribution of diet to cardiovascular disease and cancer risk***

In Europe, CVD and cancer account for almost two thirds of the overall burden of disease <sup>9</sup>. Although there is clearly a large number of risk factors for cardiovascular disease, conservative estimates suggest that about one third of CVD can be attributed to inappropriate nutrition, although the need for more research is widely acknowledged <sup>22</sup>. A report by the World Cancer Research Fund and the American Institute for Cancer Research <sup>13</sup> estimated that improved diet, along with maintenance of physical activity and appropriate body mass, could reduce cancer incidence by 30–40% over time. A widely cited estimation of the diet-related burden of cancer was made by Doll & Peto <sup>23</sup>, attributing about 35% of all cancer deaths in the United States to diet (excluding alcohol), with a range of plausible estimates of between 10% and 70% . Doll later proposed that the evidence available up to the early 1990s associating diet with cancer had become stronger, and proposed a narrower range of 20–60% <sup>24</sup>.

The specific dietary components that have the largest effect on cardiovascular disease and cancer remain a matter for debate. Earlier epidemiological and clinical studies

focused on the amount of dietary fat consumed <sup>25</sup> and the risk of heart disease. More recently the differential impacts of types of dietary fats have received attention, including trans fatty acids and animal fats <sup>26 27</sup>. Other recent ecological studies of changes in cardiovascular disease after the political transition in Poland <sup>28 29</sup> suggest that changes in dietary fats, increased fruit intake and decreased smoking rates can bring about reductions in cardiovascular disease mortality over very short timescales. The authors concluded that changes in dietary fat were more important than other risk factors, including increased fruit intake. However, these conclusions were reached despite limitations of their methodology for measuring changes in total fruit and vegetable intake<sup>30</sup>.

Other diet-related factors, in particular a wide range of micro-nutrients, have also been studied in relation to the risk of CVD and cancer. Excess energy intake is associated with increased risk for many diseases, and alcohol is a risk factor for some cancers (mouth, pharynx, oesophagus, liver) and CVD <sup>31</sup>. However, it was not until recently that fruit and vegetable intake was considered seriously as a key risk factor for non-communicable disease.

### **Evidence for a link between fruit and vegetable intake and disease**

Accumulating epidemiological evidence has suggested a strong protective effect of fruit and vegetable intake for cardiovascular diseases and some cancers <sup>12 13 32-35</sup>. The review by the World Cancer Research Fund (WCRF) and the American Institute of Cancer (AIC) of the determinants of a wide range of cancers <sup>13</sup> concluded that the evidence for fruit and vegetables decreasing cancer risk was convincing for lung and digestive tract cancers. The WCRF/AIC review concluded that, for other cancers, there was only a probable association with fruit and vegetable intake (larynx, pancreas and bladder cancers) or limited evidence of an association (cancers which may have a hormonal aetiology including ovary, endometrium, thyroid and prostate). There is also limited evidence for the link between fruit and vegetable intake and other health outcomes such as diabetes, chronic obstructive pulmonary disease and cataract <sup>36 37</sup>, but the number of published studies is currently too limited to draw conclusions on the size of any effect.

In 2003, an international review panel convened by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) assessed the strength of the evidence for the relationship between fruit and vegetable intake and health. They



concluded that increased consumption of fruit and vegetables was convincingly linked with reduced risk of cardiovascular diseases, a probable reduced risk of some cancers, diabetes and obesity, and was associated with the prevention and alleviation of several micronutrient deficiencies (especially in less developed countries) <sup>12</sup>. The review panel recommended daily intake of an “adequate quantity” of fresh fruit and vegetables to reduce these disease risks. They defined an adequate quantity to be 400 to 500g/day.

The next sections set out a summary of the relevant literature for those six disease outcomes where there is the most convincing evidence for the link between fruit and vegetable intake and disease.

### **Coronary Heart Disease**

Four recent reviews of the association between fruit and vegetable consumption and coronary heart disease were identified <sup>32,33,38,39</sup>. The review by Klerk et al. <sup>32</sup> concluded that a high versus a low consumption of fruit and vegetables (increasing from 250 to 400g/day) is likely to reduce the risk of coronary heart disease by 20–40% in men and women; however, the methods used to derive the final estimates are unclear.

The review by Ness and Powles <sup>33</sup> identified 10 ecological, 3 case–control and 16 cohort studies investigating coronary heart disease. Of these, nine ecological studies, two case–control studies, and six cohort studies reported a statistically significant negative relationship between coronary heart disease and the consumption of fruit and vegetables or proxy nutrients. Ness and Powles did not attempt to arrive at a summary statistic for the association as the measures of exposure and disease varied considerably between studies. They concluded that the results are consistent with a protective effect of fruit and vegetables for coronary heart disease.

Law and Morris <sup>38</sup> performed a meta-analysis of cohort studies that had examined the relationship between ischaemic heart disease and markers of fruit and vegetable consumption, namely dietary intake of fruit, vegetables, carotenoids, vitamin C, fruit fibre and vegetable fibre, and serum concentration of carotenoids and vitamin C, adjusting for other factors. They estimated that the risk of ischaemic heart disease is about 15% lower at the 90<sup>th</sup> than at the 10<sup>th</sup> centile of fruit and vegetable consumption.

Most recently, Bazano <sup>39</sup> conducted a review of the effect of fruit and vegetable consumption on coronary heart disease and stroke. This identified nine prospective

cohort studies evaluating the relationship between fruit and vegetable intake and coronary heart disease which had been published since the review by Ness and Powles<sup>33</sup>. Of these studies, four found significant inverse associations, while five found inverse associations which tended towards but did not reach statistical significance after appropriate adjustment.

### **Ischaemic Stroke**

Four recent reviews that previously studied the association between fruit and vegetable consumption and stroke were identified<sup>32 33 39 40</sup>. The review by Klerk et al.<sup>32</sup> concluded that the risk of stroke is reduced by 0–25% with higher intakes of fruit and vegetables. The 1997 review by Ness and Powles<sup>33</sup> identified five ecological, one case–control and eight cohort studies reporting measures of association between the intake of fruit and vegetables and stroke. Of these, three ecological studies and six cohort studies reported a statistically significant negative association with the consumption of fruit and vegetables or proxy nutrients. The authors concluded that the results of both reviews were consistent with a strong protective effect of fruit and vegetables for stroke, but they did not calculate a summary statistic for the association as the measures of exposure and outcome varied considerably among studies<sup>33 40</sup>. A recent review by Bazzano (2005)<sup>39</sup> identified eight prospective cohort studies evaluating intake of fruit and vegetable intake and risk of stroke which had been published since the review by Ness and Powles<sup>33</sup>. Of these studies, five found significant inverse associations, while three had inverse associations which tended towards but did not reach statistical significance after appropriate adjustment. Subsequent to the work for this thesis (chapter 6), He et al.<sup>41</sup> conducted a meta-analysis of the association between fruit and vegetable consumption and stroke. The paper by He and colleagues does bring this work up to date since they were able to include several studies that were not yet published when I undertook the review. Additionally, I had to exclude two of the studies they included because they did not provide exposure data in the format required for the comparative risk assessment used in the Global Burden of Disease study. Since the comparisons chosen by He and colleagues are different, I cannot directly compare the figures, but they seem consistent.

## **Lung Cancer**

Five recent comprehensive reviews of the association of fruit and vegetable intake with lung cancer risk were identified. Three concluded that there was convincing evidence that a diet rich in fruit and vegetables decreases the risk of lung cancer.

One of these three reviews was by the World Cancer Research Fund and the American Institute of Cancer <sup>13</sup> which reviewed 7 cohort and 17 case-control studies. Of the 7 cohort studies, all showed a protective association for some fruit or vegetables, after adjustment for smoking. Most of the relative risks (23 of 31) they presented indicated a protective association, although not all were statistically significant. No studies showed a statistically significant increase in risk for consumption of any type of fruit or vegetable. Sixteen of the case-control studies reported statistically significant inverse associations for one or more vegetable or fruit categories. The evidence was most abundant for green vegetables and carrots. Results of an analysis examining the dose-response relationship between vegetable intake and risk of lung cancer estimated that the relative risk decreases by about 50% as intake increases from 150g/day to 400g/day. An intake of >400g/day is always associated with a lower risk than is 100g/day or less.

In their review, Ziegler et al. <sup>42</sup> asserted that the results of observational studies of diet and lung cancer suggest strongly that an increased fruit and vegetable intake is associated with a reduced risk in men and women; in various countries; in smokers, ex-smokers, and never-smokers; and for all types of lung cancer.

The review by Klerk et al. <sup>32</sup> concluded that high versus low consumption of fruit and vegetables (an average difference of 150 g/day) is likely to reduce the risk of lung cancer by 35–55% in men and women.

Koo <sup>43</sup>, in contrast, concluded that epidemiological studies performed over the last 20 years do not provide overwhelming evidence of an inverse association between fruit and vegetable consumption and lung cancer risk. Koo proposed the imperfect control of smoking-associated dietary correlates and “lifestyle” differences as the major problems with the perceived associations between diet and lung cancer. Koo’s work should, however, be interpreted in the knowledge that she been closely involved with several scientists involved in the campaign developed by tobacco industry lawyers to undermine the link between passive smoking and disease. A major component of this programme has been to argue that much research on risk factors, and in particular the

association between passive smoking and disease, is unreliable because of unmeasured confounding <sup>44</sup>.

A meta-analysis of the association between fruit and vegetable consumption and lung cancer is the only other attempt, apart from this study, to pool cohort study results and obtain a summary estimate of the size of the effect <sup>45</sup>. Controlling for smoking habits and other risk factors for lung cancer, a 17–23% reduction in lung cancer risk was observed for total fruit intake for quintiles 2 through 5 versus the lowest quintile of intake (RR=0.77, 95% CI 0.67–0.87 for quintile 5; P-value test for trend <0.001). A weaker association was observed for total vegetables (RR = 0.88, 95% CI 0.78–1.00 for comparison of quintile 5 vs 1; P-value test for trend >0.12). Associations were similar among never, past, and current smokers.

### **Stomach cancer**

Four recent reviews of the literature concluded that epidemiological evidence shows a consistent protective effect of fruit and vegetable intake on risk of stomach cancer.

The report from the World Cancer Research Fund and the American Cancer Institute <sup>13</sup> reviewed 6 cohort and 32 case–control studies. Three of the 6 cohort studies, and 27 of the 32 case–control studies reported a statistically significant protective association for one or more vegetable or fruit categories. The evidence for raw vegetables, allium vegetables and citrus fruit in particular is consistent with a protective effect. Any contradictory evidence related entirely to salted and pickled vegetables. Analyses of dose–response relationships suggested that the risk of stomach cancer decreases by about 50% as fruit and vegetable intake increases from 50 g/day to 300 g/day. An intake of >150g/day is always associated with a lower risk than 100 g/day or less. In comparison, the review by Klerk et al. <sup>32</sup> concluded that high versus low consumption of fruit and vegetables (an average difference of 150 g per day) is likely to reduce the risk of stomach cancer by 40–55% in men and women.

A meta-analysis by Norat et al. <sup>46</sup> of published case–control and cohort studies examined the association of total fruit or total vegetable consumption with gastric, colorectal and oesophageal cancer. It included all studies published in English from 1973–2000 and referenced in Medline that provided data on total fruit or vegetable intake. There was no assessment of study quality, adjustment for confounders was not assessed, and studies were included as long as they could provide the information

necessary for the statistical analysis. For gastric cancer, 32 studies were included that analysed total fruit intake and 22 studies were included for total vegetable intake. The pooled relative risks associated with an increase of consumption of 100g/day were: 0.75 (95% CI 0.67–0.83) for fruits; and 0.80 (0.74–0.86) for vegetables.

### **Colorectal cancer**

Four recent comprehensive reviews of the literature investigating fruit and vegetable consumption and risk of colorectal cancer were found. They all concluded that the evidence is consistent in supporting a decreased risk of colorectal cancer with higher consumption of vegetables, and that data for an association with fruit consumption is inconsistent<sup>13 32 46 47</sup>. Only two of these attempted to quantify the relationship.

The review by Klerk et al.<sup>32</sup> estimated that high versus low consumption of fruit and vegetables (an average difference of 150 g per day) is likely to reduce the risk of colorectal cancer by 20–45% in men and women.

The meta-analysis by Norat<sup>46</sup> (see description above in the section on stomach cancer) included 13 studies assessing the effect of total fruit intake and 28 studies assessing the effect of total vegetable intake. The pooled relative risks associated with an increased intake of 100 g/day were: 0.94 (95% CI 0.90–0.98) for fruits; and 0.90 (95% CI 0.84–0.96) for vegetables (sub-analyses found similar relative risks for men and women, and for European and American populations).

### **Oesophageal cancer**

Three recent reviews of the literature;<sup>13 48</sup> concluded that there is convincing evidence that diets high in fruit and vegetables decrease the risk of oesophageal cancer.

The World Cancer Research Fund and the American Institute of Cancer reviewed 22 case–control studies<sup>13</sup>. Of these, 18 showed a statistically significant protective association with at least one category of fruit or vegetables. The protective association reported in the studies remained after controlling for smoking and alcohol consumption. The review by Klerk et al.<sup>32</sup> concluded that high versus low consumption of fruit and vegetables (an average difference of 150g per day) is likely to reduce the risk of oesophageal cancer by 40–55% in men and women.

Finally, the meta-analysis by Norat et al.<sup>46</sup> pooled the results of 10 studies assessing the effect of fruit intake and 11 studies assessing the effect of vegetable intake on oesophageal cancer (see more details of methods described in the section on stomach

cancer). This estimated that an increase in food intake of 100 g/day is associated with a relative risk for oesophageal cancer of 0.79 (95% CI 0.65–0.95) for fruits; and 0.92 (95% CI 0.85–1.01) for vegetables.

## **Conclusion**

This consistent pattern of findings, suggesting a diet rich in fruit and vegetables has a role in the prevention of CVD, stroke and some cancers, has led several national and international organisations to advocate an increase in individual intake to at least 400g of fruit and vegetables per person per day (excluding potatoes and other starchy tubers)<sup>12, 13, 49</sup>. However, survey data and fruit and vegetable availability statistics from the FAO<sup>50</sup> suggest that most populations are not meeting this recommendation and that new approaches to increase fruit and vegetable consumption in the population are urgently needed.

## ***Food policy as a public health policy***

Public policy has been defined as the sum of policies that shape contemporary environments in different settings including communities, schools, workplaces<sup>51</sup>. Other authors propose that public policies must have been generated or processed within the framework of governmental procedures and organisations<sup>52, 53</sup>. There are two major elements in these concepts of public policy; firstly, that public policies have a broad environmental impact; and secondly, that they are linked with the leadership and organisation of large administrative units of government (whether that be at international, national, regional or local levels). As many public policies have health impacts<sup>51 54 55</sup>, and because public health deals with processes that mobilise local, national, regional and international resources to ensure the conditions in which people can be healthy, it can be argued that there is only a marginal difference between public policies and public health policies. The task of public health policy is to address public health consequences of any public policy. When one thinks of a specific public health policy such as tobacco or tuberculosis control the task of the policy becomes clearer, including its links to other policies (for example in tobacco or alcohol policy there are clear links with fiscal and tax policy and market regulations). However, because public health policy is directed towards tackling the determinants of disease and ill health, the focus may often be outside the health sector<sup>54</sup>. Clearly food and agriculture policy have large public health impacts, both positive and negative, and are important public policies that should consider health.

Across Europe food is increasingly considered a public health issue requiring policy formation. The concept of food policy differs from country to country, with the main policy links between food and public health often focusing on two very different issues; food safety and the promotion of healthy diets. The following examples from Finland, France and Sweden show that variations in policies amongst individual countries appear to be shaped by differences in the understanding of factors that impact on public health.

In Finland, public health policy has previously targeted individual disease risk factors, including diet. The Finnish approach is based on the success of the North Karelia Project, which was started in the 1970s with the goal of reducing cardiovascular disease<sup>56</sup>. This project succeeded in reducing rates of cardiovascular disease by 73% in the working age population over 10 years, with changes in risk factors estimated to account for 89% of the decline. This was achieved by adopting a range of interventions aimed at smoking, diet, alcohol and physical activity. Interventions included provision of information to the public, strengthening health services, encouragement of environmental changes (such as smoking restrictions, promoting vegetable growing), and training and education of health personnel in disease risk factors and behaviour change.

In France in 2001 a strategic national plan on nutrition focused on the promotion of good nutritional habits (*Programme national nutrition santé*, described in English at <http://www.sante.gouv.fr/htm/pointsur/nutrition/index.htm>). This aimed to reduce the prevalence of adult obesity by 20%, and to prevent childhood obesity. The plan emphasised prevention in children and has included nutritional health education in schools, individualised obesity management for adolescents, and linkages between diet and physical activity programmes. It has not achieved its goals, as obesity rates continue to rise in France.

The Swedish National Health Policy has also included an emphasis on healthy eating. In a study at county level in Sweden, dietary advice emerged as the most cost-effective strategy in a model which simulated costs and effects of different preventive measures. However, this is not the sole focus of policy in Sweden as the Government is currently considering a multi-sectoral obesity strategy. Sweden also has a strong history of assessing the public health impacts of broader policies affecting food and nutrition, including agriculture, and it has banned food marketing to children<sup>57 58</sup>.

The wide variation in approaches to food policy by the public health sector across Europe may to some extent be based on differences in understanding (or acceptance) of the factors affecting dietary intake. It is well known that the nutrition transition, occurring in all but the poorest countries of the world, is resulting in the replacement of a traditional plant-based diet rich in fruit and vegetables by a diet rich in calories provided by animal fats and low in complex carbohydrates <sup>59</sup>. Such changes will generally lead to increased rates of many non-communicable diseases in countries previously protected by balanced and healthy diets <sup>60</sup>. Rising income is the main driver of the nutrition transition. As populations improve their standard of living, sales of animal-based foods increase. However, the relationship between rising wealth and rising demand for animal-based foods is not simple as available supplies and marketing activities shape consumer demand. Yet knowledge of these trends has not led to significant change in food policies.

As well as increased concern by the public health community, health services are also becoming conscious of the share of their budgets devoted to food-related ill health. For example, in the UK, a government report estimated that treating obesity costs the NHS at least £1½ billion a year, while the wider costs to the economy in lower productivity and lost output could be a further £2 billion each year <sup>61</sup>. Consequently, some policy-makers are beginning to look at wider determinants of diet related ill-health, turning their attention upstream, rather than solely focusing on diagnosis and treatment, or promotion of 'healthy lifestyles' in individuals. There is an increasing awareness that there are structural and environmental factors and policies which affect attainment of 'healthy lifestyles' and specifically nutrition goals. These include:

- Providing appropriate information and education relating to food, nutrition and physical activity at all age groups in a range of settings;
- Formulating nutritional standards for food composition and catering;
- Regulating food labelling, advertising, promotion and health claims;
- Evaluating the impact of pricing and retailing strategies.

However, one of the major influences on diets, agriculture and food production, is usually not considered in these broad public health policies.



## ***The role of European Union policy in determining diet and health***

Two main European Union (EU) policies have a direct impact on nutrition and health, namely the Common Agricultural Policy in place since 1962 (mostly focused on the supply side of the food chain) and the Health and Consumer Protection strategy (focused on the demand side) which was adopted in 2005 and preceded by the Health Strategy from the year 2000. These two policies are interlinked via food safety which forms the basis for any consideration of health issues concerned with food in the EU. Another obvious connection between the two policies is nutrition, which currently ranks much lower on the political agenda in Brussels. The broader public health issues, including nutrition, should be incorporated into every EU policy, according to article 152 and 153 of the Amsterdam Treaty but are too rarely considered by decision makers.

Within the Health and Consumer policy several pending directives are of importance for food demand. These include the Health Claims Directive and the Food Labelling Directive. Furthermore, there are other important areas that have not yet been tackled, for example the absence of an EU-wide regulation on marketing of food directed at children.

The public health implications of European agricultural policy have risen in prominence since the discovery in the United Kingdom of the link between bovine spongiform encephalopathy (BSE) in cattle and new variant Creutzfeld-Jakob disease (nv-CJD) in humans<sup>62</sup>. Since the emergence of BSE, policy-makers across Europe have given a high priority to food safety, culminating in the recent establishment of the European Food Safety Authority in Parma, Italy. Food safety is considered the major agricultural-related health issue despite evidence showing the greater contribution of nutrition and food security to the burden of disease<sup>9 63</sup>. This policy emphasis is probably because food contaminants are perceived to be beyond consumer control, but also political concerns for preserving the competitiveness of European agriculture. Nutrition is still perceived by many as an issue of individual choice. Therefore it does not attract the same level of attention from politicians and administrators who assume that agricultural production is a 'perfect market' where the demand for food controls the supply. Nothing could be further from the truth. The CAP regulations influence both the availability and the affordability of food and therefore also influence the demand. It is impossible to address food and nutrition policy without looking at the

agricultural policy that defines, to a large extent, the foods that are available and affordable for consumption.

**The EU Common Agricultural Policy**

A comprehensive European agricultural policy was a key element from the outset in the formation of the European Community. One of the original policy drivers was population health, driven by the memory of post-World War II food shortages and the need to improve future food supplies in Europe. While the fundamental goal of many agricultural policies remains the provision of adequate food to feed the population, the precise situation in each country, and across Europe, reflects a much more complex combination of influences of policy imperatives from the agriculture, food, trade, retail and health sectors.

The Treaty of Rome defined the general objectives of the Common Agricultural Policy (CAP), which remain essentially unchanged until the present day <sup>64</sup>, placing consumer price and food security at its heart (Figure 1-1).

**Figure 1-1 Objectives of the CAP as set out in Article 33 of the EC (Amsterdam) Treaty**

- To increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilisation of the factors of production, including labour
- To ensure a fair standard of living for the agricultural community, by increasing individual earnings of those employed in agriculture
- To stabilise markets
- To assure the availability of supplies
- To ensure that supplies reach consumers at reasonable price

Historically several policy instruments have been used to achieve the CAP objectives. From 1962 to 1983, price subsidies were used with the multiple aims of increasing production (including efficiency), improving income support and stabilising markets. These price support mechanisms included import tariffs, market interventions and export subsidies and resulted in higher prices in the EU markets. The effects of the policy were both positive and negative. The CAP was successful at achieving its initial goals of increased production and productivity, stabilising European markets and securing food supplies. The result was that the EU became a net food exporter. Similar

policies were adopted in the COMECON countries in eastern Europe. By the mid-1970s, strong national and regional measures to support agriculture had helped ensure better agricultural supplies within the European Region, in both the western democracies and the Communist bloc. In general, there was plenty to eat, and a huge food processing industry had become well established. However, these had to be balanced against several negative side effects including the higher costs to consumers and the unfair distribution of agricultural support (with 80% going to the 20% of biggest farms). The end results were production surpluses and rapid increases in agricultural spending.

Since 1970 food surpluses have constituted a costly problem for the agricultural sector in the EU. From 1984-1992, policy instruments, including quotas, set aside policy and price support mechanisms, were introduced to halt the increase in production and control expenditure on agriculture. This solved the problem in the milk sector but most of the other surpluses and budgetary problems remained.

Direct payments were introduced in 1993 in order to conclude the GATT/ World Trade Organisation negotiations and to stabilise budgetary costs and farm incomes. Price support mechanisms were reduced and other types of payments introduced to guarantee farm incomes, including direct payments per hectare/head, payments for set aside land and payments for environmental reasons and less favoured area status. This did have the effect of stabilising the CAP budget while also stabilising farmers' incomes.

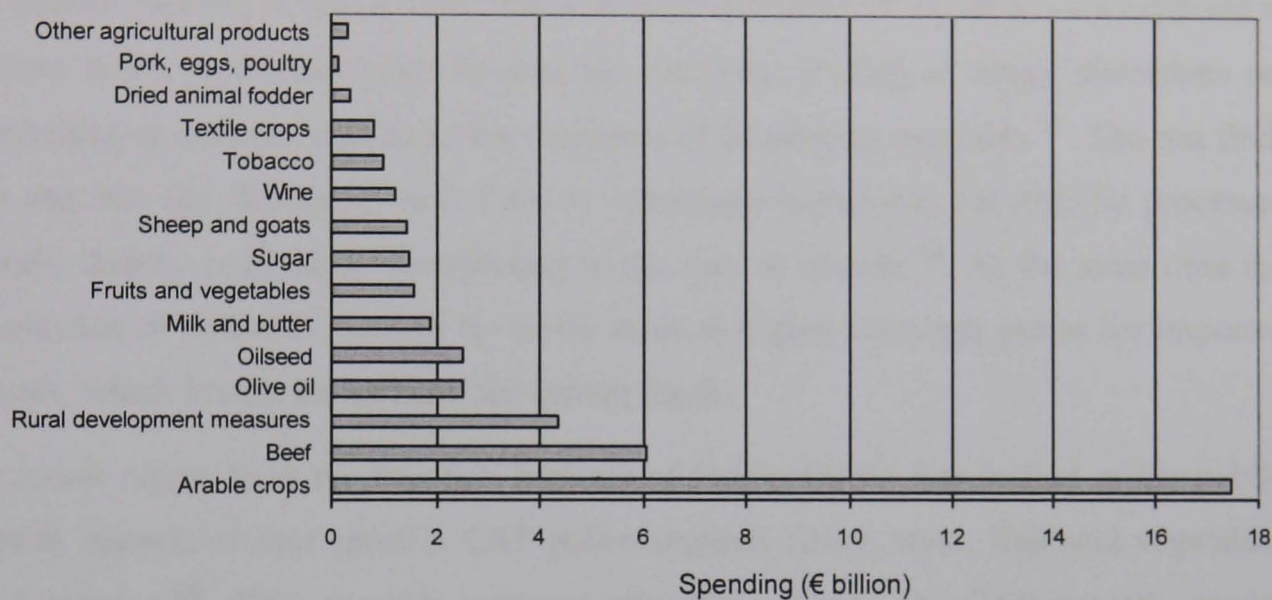
Longstanding incentives favouring overproduction led the 2003 CAP reform to partially decouple the financial support paid to farmers from actual production levels in a number of sectors (arable crops and livestock)<sup>65</sup>. Today, agriculture policy has additional objectives related to rural development and environmental protection for which farmers can be paid.

Thus, although the CAP has undergone several reforms since its creation 40 years ago, these are essentially matters of detail, with none being driven by public health considerations <sup>58</sup>. The CAP thus continues to focus largely on yields and quantities produced and expanding international trade. The nutritional implications of the CAP are not considered. Consequently, it has driven the production of foods in directions that may not be best suited to optimum population health. For example, the CAP gives

considerable financial support to the production of meat and milk, which are both relatively expensive in environmental and financial terms but also rich in saturated fat.

In western Europe, the largest share of CAP funds has supported cereal farming, but about half of the cereal produced is used for animal feed. (Figure 1-2).

**Figure 1-2 CAP spending by the European Agricultural Guidance and Guarantee Fund according to the products sector, 2001**



Source: Robertson et al <sup>66</sup>, adapted from 31<sup>st</sup> financial report on the European Agricultural Guidance and Guarantee Fund EAGGF, Guarantee Section – 2001 financial year <sup>67</sup>.

It is important for these figures to be set against the total output value of each food type. For example, although the European Agricultural Guidance and Guarantee Fund appears to spend comparable amounts on supporting the production of both sugar and fruits and vegetables, this support amounts to 47% of the output value for the former but only 4% for the latter <sup>68</sup>. These differences may lead to substantial distortions in the market. In a series of papers on the workings of CAP, the European Court of Auditors has criticized the butter <sup>69</sup>, sugar <sup>70</sup> and milk <sup>71</sup> regimes for protecting and promoting surplus production for the benefit of producers.

By subsidizing the production of certain foods, the CAP has separated the producer from the consumer in the marketplace. It has created an artificial market for producers that may not reflect consumers' preferences, thus counteracting consumer pressure for diets that promote health <sup>58 72</sup>.

## **The health impact of European agriculture policy**

Agriculture policies have profound and complex effects on the food supply as well as on demand because policy creates production incentives for many commodities by providing market support. Traditionally in the EU, the most heavily subsidised sectors are cereals, beef, olive oil and milk<sup>58</sup>. Even commodities with potential or real adverse consequences for health, like tobacco, wine and sugar, are receiving substantial economic support. A considerable share of the food surpluses in the EU are exported at prices below production costs because of subsidies, leading to major distortions on international markets, usually to the detriment of developing countries<sup>73</sup>. The rest finds its way into the European food chain as subsidised ingredients for high-fat processed foods, thereby most likely contributing to the rise in obesity<sup>74</sup>. At the same time the protection of domestic markets by tariffs leads to higher consumer prices for imported goods, which lowers the demand for certain foods.

A recent report from the Swedish Institute of Public Health has looked at the public health impacts of four specific CAP policy regimes (dairy, wine, fruit and vegetables and tobacco)<sup>58</sup>. This provides concrete examples of how the CAP actually works against dietary recommendations. For example, dairy producers are given greater incentives to produce high-fat rather than low-fat milk; and excess dairy fat produced in the EU is converted to half a million tonnes of surplus butter each year. This corresponds to one third of EU consumption, and is sold at a discount (with further subsidies) to the food industry for food processing<sup>58</sup>.

This report concludes that:

*'The CAP has become more health-oriented since 1996 in terms of food safety. However, risk factors of cardiovascular disease, cancer, diabetes and alcohol-related diseases, are still not taken into consideration as required under the Amsterdam Treaty.... From a public health perspective, the tax money transferred to agriculture could be of greater benefit to citizens if spent in other ways.'* (Schafer Elinder 2003)

The EU has a small budget for food promotional activities and, until 1999, devoted it almost entirely to promoting meat (especially beef) and dairy products (especially butter and full-fat milk)<sup>58 75</sup>. The EU has also supported distribution schemes, offering low-price foods to hospitals, schools and other institutions. These, too, have focused on



meat and dairy products, and only limited fruit and vegetable distribution has taken place.

The specific aspects of how the EU Common Agricultural Policy's fruit and vegetable regime can impact on population health is discussed in Chapter 11 where the results of the health impact assessment in Slovenia are presented.

The financial support for animal-derived products has led to a shift in the use of agricultural land towards livestock rearing rather than crops for human consumption. Three quarters of agricultural land in the EU is now used for animal feed and grazing<sup>76</sup>. Among the five pre-2004 EU countries in southern Europe, the land area devoted to fruit and vegetable production has declined by over 20% in the last four decades, while that for grain production for animal feed has increased by 20%.

Although the CAP is an important determinant of food availability and price, this does not imply that agricultural policy in Europe solely determines the consumption of foods and hence the population's dietary patterns and nutritional status. The chain of causality is complex. While rising income is a major driver of the nutrition transition from plant- to animal-based foods other factors shape demand, including changes in food availability, the power of the retail sector and marketing activities. For example, in Europe, as more people have shifted their diet from plant to animal products, animal production has increased, aided by agricultural incentives, leading to falling prices, which encourages their consumption<sup>66</sup>.

In health terms, the CAP should be seen as a policy failure as it does not produce the range of foods that would allow the population of Europe to meet basic healthy eating recommendations<sup>77</sup>. This basic contradiction demonstrates a key problem with the CAP as a major determinant of diet.

At present, European agricultural policy takes no account of concerns about the contribution to poor nutrition and consequently the rise in non-communicable disease, despite the clear epidemiological evidence of the benefits of a healthy diet rich in fruit and vegetables and low in dietary fat, sugar and salt. It does not appear that evidence of the relationship between nutrition and disease has had any influence on recent agriculture policy in Europe. As dietary habits are deeply embedded in cultural, economic and political structures there should be greater emphasis on promoting policies that target the determinants of consumption rather than the current focus of

many health policies which simply target health education and targeting individual behavioural change.

### ***The challenge of assessing the health effects of agriculture and food policy***

It is clear that patterns of food consumption, and low fruit and vegetable consumption in particular, are key risk factors for major non-communicable diseases. However, as described above, the nutritional burden of disease and concerns over agricultural-health linkages do not seem to have had major impact on agricultural policy formation in Europe, except where this has had other, usually economic, impacts (such as BSE and food safety).

### ***Aims and objectives of the thesis***

This thesis aims to investigate how public health evidence can be used better to inform and influence the development of food and agriculture policy in Europe. It sets out to achieve this by applying two methods that have been advocated as tools for evidence-based policy making in public health, health impact assessment of agriculture and food policy and calculation of the burden of disease due to nutritional risk factors. Using the fruit and vegetable sector as a case study, this thesis develops and applies these two methods as a means of informing considerations of the health effects of policies on fruit and vegetable production, promotion and/ or consumption. The research was grounded in a practical setting, working with policy-makers in the Republic of Slovenia. These two methods were selected as they illustrate two extreme models of evidence-based public health; that of research-based, expert conducted analysis, producing quantitative estimates, compared with a participatory, inter-sectoral approach to collecting and analysing more contextual data. The thesis analyses the strengths and limitations of the methods as applied to the fruit and vegetable sector. It explores the different roles that such methods might play in food and agricultural policy development and their scope for further improvement.

### ***Structure of the thesis***

Chapter 2 will provide a discussion of the background to the purpose and methods of burden of disease analysis and health impact assessment approaches used in the thesis. Part two of the thesis focuses on the application of burden of disease analysis to the fruit and vegetable sector, globally and in Slovenia. Chapters 3-7 will present in detail

the methods used and results of estimating the burden of disease attributable to low fruit and vegetable consumption. Chapter 8 shows how these methods were adapted and applied to the national situation in the Republic of Slovenia. Chapter 9 discusses the strengths and limitations of the burden of disease (and disability adjusted life years) approach applied to the policy process.

Part three of the thesis focuses on the application of health impact assessment to the fruit and vegetable sector. Chapter 10 presents the health impact assessment methods that were developed and applied in Slovenia to assess the potential impact of the Common Agricultural Policy after European Union. Chapter 11 presents the results of the assessment focusing on the impact on the fruit and vegetable sector. Chapter 12 discusses the strengths and limitations of the health impact assessment approach in a national policy context.

The final chapter, 13, draws conclusions on the implications of this research for improving the use of health evidence in agricultural and food policy-making on population health grounds.



## **Chapter 2 Burden of disease studies and health impact assessment: methods for evidence- based public health policy**

Understanding how evidence can better influence government policy requires an understanding of how public policy is developed, and what influences the policy process. Although this is not the main subject of this thesis, the main concepts of evidence- based policy will be introduced to frame subsequent discussions, together with a background and overview of the two methods used in this thesis; health impact assessment and burden of disease analysis.

### ***Defining policy and the nature of the policy process***

The word *policy* has various interpretations. Authors dealing with policy issues have defined it in a number of ways highlighting the complexity of the concept. It has been argued that policy involves a purposive course of action involving a chain of related activities and a series of decisions. This process is influenced by personal, group, organisational and other circumstances<sup>52 53</sup>. Policy also involves implementation. Another interpretation is that policy is an attempt to do something about a problem, and as such is an attempt to define and structure a rational basis for action or inaction<sup>78</sup>.

*'Policy as a term becomes the expression of political rationality. To have a policy is to have rational reasons or arguments which contain both a claim to an understanding of a problem and a solution. It puts forward what is and what ought to be done. A policy offers a theory upon which a claim for legitimacy is made. In liberal democratic systems political elites have to give rational reasons for what they propose or what they have done' (Parsons 1995<sup>78</sup>).*

Political scientists traditionally summarised the policy process in four key stages; agenda setting or issue statement, policy formulation or planning, implementation and evaluation<sup>52 53 78</sup>. However, recent theories stress that in reality these stages are not necessarily so clearly defined, nor follow one another in a fixed sequence<sup>53</sup>. So the policy process is recognised as being iterative not linear, with multiple influences at all stages.

Discussing the policy process using the concept of stages, however, assists in conceptualising how different influences, including health evidence, may affect the process. Agenda setting occurs when policy makers identify a problem and develop

broad goals to be addressed <sup>79</sup>. When governments set agendas, health issues compete against other government priorities such as economic growth, and public health issues must compete with health care issues. Public health advocacy is often an important element of the process of placing an issue on the policymaking agenda. Several factors make it more likely that an issue will reach the agenda:

- The greater the number of people who perceive that the problem exists;
- The greater the perceived severity of the problem;
- The more immediate and novel a problem is perceived to be;
- The more likely it is to affect an individual personally.

To become part of the public policy agenda, policy makers need to consider that the issue is in the public interest and within the remit of government. Once it is on the agenda, policy formulation involves developing alternative proposals and then collecting, analysing, and communicating the information necessary to assess policy proposals. Policy formulation and agenda setting involve similar inputs; assembling evidence and information and developing arguments for various alternatives. There is also a degree of compromise and bargaining among the various interest groups, media, political parties and government agencies that have an interest in influencing the issue.

Once a policy is formulated, governments may take forward policy proposals in a number of ways, including laws, regulations, and resource allocation decisions. Policy implementation involves interpretation of the policy, organisational development and application. The last step in the process is evaluation. This can have several aims including understanding how well the policy was implemented, whether the policy goals were achieved or what impact it actually had. Although policymakers do not always encourage evaluation of policies, the process often occurs either formally or informally and can affect whether a policy or programme is maintained, changed, expanded or even stopped.

This simplified model of decision-making shows that evidence could be an essential input to all stages of the policy process. However, a large literature exists which shows that health evidence has to compete alongside a large number of influencing factors and stakeholders which ultimately affect a policy output<sup>53 96</sup>. How the full range of these factors affect food and agricultural policy development in specific contexts was not the focus of this thesis but it is important to reflect on them when considering how this

research may inform public health policy. Clearly to influence decisions the public health evidence-base has to be appropriate and timely, but there is also the need for awareness amongst researchers that this may not be sufficient to move towards 'evidence-based policymaking' <sup>96</sup>.

### ***The use of evidence in public health policymaking***

Researchers are currently engaged in applying the principles of evidence-based medicine <sup>80</sup> to many fields of practice. The growing acceptance of these principles has encouraged policymakers to think about what works and to look for evidence that demonstrates the effectiveness of policies and interventions. Interest in evidence for decision-making has increased rapidly, and many commentators are asking about the extent to which public health policy, as currently manifest, is based on evidence <sup>81-85</sup>.

Evidence-based public health can be defined as '*a public health endeavour in which there is an informed, explicit, and judicious use of evidence that has been derived from any variety of science and social science research and evaluation methods*' <sup>80 86</sup>. The definition highlights two aspects of evidence-based public health: (i) the use of a particular type of evidence to inform public health decisions; and (ii) an emphasis on clear reasoning in the process of appraising and interpreting the evidence.

The types of research that are commonly associated with evidence-based medicine, particularly the systematic review process and use of critical appraisal criteria to judge research, are often highlighted as markers of quality in the synthesis of evidence. However, it has been argued that the complex, long term nature of public health policies and interventions often makes the principles, approaches and standards developed for clinical evidence inappropriate and hard to apply <sup>87</sup> because many different kinds of evidence are required to understand not only which public health policy interventions work but also how, why and in what circumstances <sup>88</sup>. Many of the outcomes of public health interventions are hard to measure, and become apparent only over the long term. Interventions are often delivered in different ways in diverse settings yet the concept underlying meta-analysis, seen as the gold standard for synthesising evidence, is that by pooling data one should seek to approximate to a universal measure of effect.

The definition of evidence-based public health should be sufficiently broad to encompass a wide variety of health research methods as sources of evidence. Studies

can be categorised according to the questions that they seek to answer, and it has been proposed that the evidence for evidence-based public health can encompass the following approaches, with the precise choice of method depending on the nature of the information required <sup>86</sup>:

- Descriptive: to identify the qualities and distribution of variables;
- Taxonomic: to compare and classify variables into related groups or categories;
- Analytic: to examine associations between variables (both causal or therapeutic);
- Interpretive: to identify and explain meanings from particular perspectives;
- Explanatory: to make observations understandable;
- Evaluative: to determine quality and worth, often assessing the relevance, effectiveness and consequences of activities.

Some proponents of evidence-based public health argue for greater specificity in the type of research that is considered as evidence for public health. Brownson et al <sup>81 89</sup> categorise two types of evidence; type 1 is research that describes risk-disease relationships, and identifies the magnitude, severity of the public health problem. This most often identifies that a public health issue exists and that something should be done about it. Examples include burden of disease studies. Type 2 evidence identifies the relative effectiveness of specific interventions aimed at addressing a problem. This determines what should be done. Examples include controlled trials of interventions and economic evaluations. However, for evidence to inform public health policy, this taxonomy appears to be too limited. In reality there is also a third category of evidence, drawing on descriptive and/ or qualitative methods <sup>86</sup>. This may include information on the design and implementation of a policy or intervention; the contextual circumstances in which it was implemented; and information on how a policy or intervention was received. Health impact assessment is an example of a methodology that attempts to use this qualitative and contextual evidence to inform public health policymaking. Although potentially invaluable to policymakers this third type of evidence is infrequently found in published scientific papers particularly within the 'evidence based health' literature.

Methods for linking evidence to policy recommendations are less well established than methods for synthesising and appraising evidence. There are many frameworks setting out how policy is made, and how policymaking occurs in the health sector <sup>53</sup>. These demonstrate clearly that the way that evidence is used is only one factor influencing

policy-making. However, it is often not clear from the literature what is meant by the concept of the ‘use of evidence’. Some of the most frequently used definitions about ‘use of evidence’ include direct, selective or enlightening (or conceptual)<sup>90</sup>. Direct use of evidence refers to the specific use of research results. This suggests that if research results are relevant to finding a solution, the results should directly apply to the solution without much adjustment. Enlightening or conceptual use of evidence refers to research that helps to establish new goals and benchmarks, and deepens understanding of the complexity of problems. Selective use of evidence is strategic, involving use ‘to *legitimate and sustain predetermined positions*’<sup>91</sup>. Obviously different definitions of ‘*use of evidence*’ contribute to the difficulty in understanding how to make research evidence more relevant for decision-making. A recent systematic review of interview-based studies with decision-makers sought to identify barriers and facilitating factors to the use of research evidence by health policy makers<sup>90</sup>. Twenty four studies (including a total of 2,041 interviews with health policymakers) met the inclusion criteria. The review identified the most common facilitating factors as personal contact, especially two-way communication between researchers and policymakers, timeliness and relevance of the research for decision-making, and the inclusion of research summaries with clear policy recommendations. The most commonly reported barriers were absence of personal contact with researchers, lack of relevance of the research, mutual mistrust, inadequate power to implement change, and budget constraints.

This thesis focuses on two different methods that have been developed to analyse and present evidence-based health information to decision-makers; burden of disease studies and health impact assessment. They can be seen as methods that produce very different types of evidence. The rest of this chapter will provide a background to the purpose, methods and applications of these two approaches.

### ***Burden of disease studies***

Population health has long been measured in terms of indicators based on mortality statistics. Life expectancy, all-cause and disease-specific mortality, and infant mortality are compared within and between countries. Yet even when they are disaggregated by socio-demographic or ethnic descriptors they provide insufficient information with which to make any but the most basic judgements about the health of the population or the comparative impact of a policy or intervention.

As commitment to monitoring population health and interest in rational allocation of health resources has grown, there has been increased interest in the development, calculation and use of summary measures for health policy that allow the impact of morbidity and death to be considered simultaneously. Such summary measures of population health combine information on mortality and non-fatal health outcomes to represent the health of a population as a single numerical value <sup>92</sup>. Measures have included active life expectancy (ALE), disability-free life expectancy (DFLE), and quality adjusted life expectancy (QALE). A variant on these summary measures, disability adjusted life years (DALYs) has been used by the World Health Organization, specifically in the Global Burden of Disease study <sup>93 94</sup>, and in a number of national burden of disease studies <sup>20, 19</sup>.

The justification for developing summary measures of population health is that diseases vary greatly in duration, severity and prognosis, changing over time and the life course in ways that are not captured by measures of mortality. As mortality can be measured in a simple way, and death occurs only once for each individual, the interpretation of the statistics involved is relatively straightforward. For non-fatal health outcomes there is a huge diversity, in terms of definition and measurement, of such outcomes; each person will experience several of them in a lifetime and there are many ways to aggregate these data.

Quantifying the burden of disease into a single standardised measure that expresses years of life lost to premature death plus years of healthy life lost due to disability is attractive, particularly to decision-makers, as it permits direct comparison of the impact of different risk factors and health problems. Consequently, the use of summary measures of population health has been promoted as a valuable tool in the formation of health policy and resource allocation, offering a means to incorporate population health need <sup>95</sup>.

There are at least eight possible applications of summary measures of population health <sup>96</sup>. These can be grouped into three main categories (Table 2-1).

**Table 2-1      Potential applications of summary measures of population health**

Category of potential applications	Examples
Descriptive/ explanatory applications	Comparing the health of one population to the health of another
	Comparing the health of the same population at different points in time, and thus describe changes in health of a certain population
	Identifying and quantifying overall health inequalities within populations
Policy applications	Providing appropriate and balanced attention to the effects of non-fatal health outcomes on overall population health
	Informing debates on priorities for health service delivery and planning
	Informing debates on priorities for public health, and for research
	Analysing the benefits of interventions for use in cost-effectiveness analysis
Other	Improving professional training in public health

This thesis considers the relevance of summary measures of population health (in particular DALYs as outputs of burden of disease studies) for public health policy. Potentially, such measures might provide information for health policy at three levels: firstly, the systematic presentation of the distribution of health within and between populations could be an important input into the development of policy in the social sector, identifying populations with the greatest burden of disease. The second application focuses on the elimination or reduction of specific diseases and risk factors. A comparison of the burden of disease attributable to specific risk factors or diseases can inform priority setting among public health programmes. Finally, these measures can be used in health service planning <sup>97</sup>.

In this thesis I consider the application of burden of disease studies to policies that fall into the second of these categories, specifically those designed to reduce food and diet-related diseases and related risk factors as part of a public health policy, using the example of low fruit and vegetable intake.

Two assumptions underpin the analysis of the burden of diet-related ill health: (i) that diet is a primary cause of disease or a factor that can reduce disease, and (ii) that the

extent of this causation can be measured. As will be shown in chapters 3-8, reaching agreement about the existence of a causal relationship and measuring its extent are not simple. For many diseases, fruit and vegetable consumption is only one of many contributory factors (such as smoking or lack of physical activity as risk factors for cardiovascular disease), and its impact may vary in different circumstances, for example, culturally, or seasonally, or due to genetic differences between populations.

### **The Global Burden of Disease Study and use of Disability Adjusted Life Years**

Two major classes of summary measures of population health have been developed. First, positive measures of health expectancy <sup>98</sup> such as health adjusted life expectancy (HALE), where estimates of overall life expectancy are adjusted according to the amount of time spent in less than perfect health or with disability; second, there are measures of health gaps, such as DALYs. It is this second application that will be considered in this thesis as it has been most applied to health policy formation. The publication of the original Global Burden of Disease (GBD) Study <sup>93</sup> was initiated in 1992 at the request of the World Bank for use in its 1993 World Development Report <sup>99</sup>. This original project had four main objectives:

- To develop internally consistent estimates of mortality from 107 causes of death, disaggregated by age and sex, for the world and eight constituent regions;
- To develop internally consistent estimates for the incidence, prevalence, duration and case fatality for 483 disabling conditions resulting from the 107 causes, disaggregated by age, sex and region;
- To estimate the fraction of mortality and morbidity attributable to 10 major risk factors, disaggregated by age, sex and region;
- To project scenarios of mortality and disability disaggregated by cause, age, sex and region to the year 2020.

Its publication marked the first time that mortality and morbidity statistics for the world's population were combined into one single summary measure. The GBD study devised the disability adjusted life year (DALY) as a common unit of measurement. This is disaggregated with respect to cause, age sex, and geographical region and reflects both premature mortality and life lived with disability. By using a universal index for the impact on society of disease and injury it attempted to provide data that can be used as a basis for rational allocation of health resources globally.



For the first GBD study, routinely collected epidemiological source data were used where they existed. Vital registration data existed for approximately 30-35% of all deaths worldwide in the year 1990. The estimates for other countries were based on sample registration data, extrapolation, or small-scale studies. Comparisons were made between countries expected to have similar patterns of cause of death structures, reflecting common mortality rates (i.e. at the same stage of epidemiological transition). To support these estimates, community level mortality surveillance studies were used. A whole range of data sources were provided by experts to estimate the duration and severity of the disabling sequelae of disease and injury. These were subjected to computer modelling, which checked the consistency of prevalence-incidence estimates for the disabling results of the diseases and injuries.

In the GBD study, disease burden was defined as the combination of premature mortality and morbidity as a result of a disease or an injury. This was calculated as the sum of years of life lost (YLL i.e. remaining life expectancy for fatal cases) plus the years lived with disability (YLD i.e. remaining life expectancy for non-fatal cases, adjusted for the degree of disability remaining). The sum of these two indices equals the DALY <sup>100</sup>, with future years discounted at a rate of 3%.

The YLL measure was defined as the standardised life-expectancy at a given age, taken from life tables. However, it was modified to reflect the value of a year of life at different ages. As children and the elderly were deemed to create a 'social burden' on other adults, a curved age-weight function is used to incorporate this. A year of life lived at the precise ages 10 and 50 is valued at 1 year. Above and below this age-range, a year of life is given a lower value, between these points it is worth more, peaking at about 24 years.

The GBD study uses disability attributable to disease or injury as its measure of non-fatal health outcome. This uses the international classification of impairments, disabilities and handicaps <sup>101</sup>. The calculation of DALYs as presently undertaken, incorporates an assessment of the years of life lost to different diseases before the age of 82.5 years for females and 80 for males (selected as representing the research team's assessment of the maximum attainable life expectancy at population level) <sup>93</sup> and the years spent in a disabled state <sup>102</sup>. Non-fatal health states are assigned values (disability weights) to enable calculation of years lost to disability, applying data derived from population surveys and studies to generate disability weights. Years lost due to

disability (severity adjusted) are then added to years lost to premature mortality to yield an integrated unit of health: the DALY; one DALY represents the loss of one year of healthy life.

### ***Health impact assessment***

Health impact assessment has been developed as a method of improving evidence-based decision making for health improvement. It is a formal approach to public health practice, using a combination of methods whose aim is to assess and predict the health consequences for a population of a policy, project, or programme that does not necessarily have health as its primary objective. It is usually conducted as a multidisciplinary process, using a structured framework to combine a range of evidence about the health effects of a proposal<sup>54</sup>. HIA usually takes into account the opinions and expectations of stakeholders including those who may be affected by a proposal, using both expert opinion and lay knowledge. Potential health impacts of a proposal are analysed and used to create evidence-based recommendations that are designed to inform the development of policy or the decision making process<sup>54 103</sup>.

Health impact assessment is based on the recognition that the health status of people and communities is greatly influenced by factors that lie outside the health sector. This broad model of health is based on the argument that a wide range of economic, political, social, psychological and environmental factors determine population health.

The main purpose of HIA is to feed into the decision-making process. It is promoted as a practical aid to help facilitate better policy making, based on evidence, focused on outcomes, and encouraging inter-sectoral collaboration<sup>104</sup>. There are numerous reasons proposed for undertaking HIA:

- To help policymakers incorporate evidence into policymaking;
- To promote cross-sectoral collaboration;
- To promote a participatory, consultative approach to policy-making;
- To improve health and reduce health inequalities in a population;
- To help policy makers use a sustainable development approach

All these reasons are seen as valid aims of a HIA. The specific HIA approach taken usually reflects the type of project or policy being assessed, the aims of the HIA and the underlying professional backgrounds of the practitioners involved. There are two main

theoretical foundations of health impact assessment; policy appraisal and promotion of healthy public policy; and environmental impact assessment or risk assessment.

For some practitioners, health impact assessment has been seen as a form of prospective policy appraisal, drawing on political and social science approaches. The idea of building healthy public policy was set out in the Ottawa Charter for Health Promotion <sup>105</sup> and subsequently it has undergone a process of embedding public health practice. The concept of sustainable development has further influenced this process, especially since the 1992 Earth Summit <sup>106</sup>, reflecting increased public awareness of the impact of the environment on health.

The principles and methods of health impact assessment are also similar to environmental impact assessment (EIA) and other types of impact analysis, for example social impact assessment <sup>107 108</sup>. The basis of EIA was set out in the US National Environmental Policy Act in 1969. Now over 100 countries and international organisations, including the European Union, have established EIA procedures, often making EIA a statutory requirement <sup>109</sup>. EIA draws on many disciplines, including risk assessment, cost benefit analysis, social science, ecology and toxicology.

It has been argued that procedures for health impact assessment would most logically be developed by including health in existing processes for EIA <sup>109</sup>. In practice, although the scope of EIA continues to broaden, most environmental assessments overlook or neglect human health effects <sup>110</sup>. Initially HIA methods developed as a natural extension of EIA methods. Health impact assessment has since been developed as a discrete tool for promoting public health in policies and projects, with methods diverging. However the differing conceptual backgrounds continue to prevail and the phrase 'Health impact assessment' includes many different activities of varying complexity.

A large number of different models of HIA now exist, accompanied by guidelines and toolkits (Table 2-2). In practice the HIA model used is adapted to the specific context and often depends on several practical considerations:

- the timescale of the proposal, since an HIA report will be unable to affect decisions taken before the report is completed;
- the resources available (time, staff, expertise, money);
- the importance of the proposal or the potential size of the health effects.

Hence, the application of HIA is often simply categorised as either rapid/ brief or comprehensive approaches (also called mini and maxi HIA <sup>111</sup>).

Brief approaches include desktop appraisal, usually taken by officers in an organisation and often using checklists to gain a snapshot of health impacts to inform the direction of proposals. Often such 'mini' HIAs only use existing information and seek no stakeholder participation. However, some 'mini'-HIAs do include rapid stakeholder appraisal workshops <sup>112</sup>. These most often involve a community-based assessment, largely using qualitative methods that are contextually embedded.

More comprehensive HIAs are much larger projects, both in terms of time and resources. They tend to have a stronger research focus, usually involving the collection of new data. They draw upon a range of quantitative and qualitative analysis, with a variable balance between the two.

**Table 2-2 Examples of models of health impact assessment worldwide**

<b>Model of HIA</b>	<b>Examples</b>	<b>Main focus</b>	<b>Method of identification of health impacts</b>
Policy analysis	British Columbia <sup>113</sup>	Possible impact of public policy on health determinants	Checklist
Environmental Health Impact Assessment (closely based on EIA)	Australia <sup>114</sup> , New Zealand <sup>115</sup> , EHIA Bielefeld, Germany <sup>116</sup> , Health Canada <sup>117</sup> , Developing countries <sup>118</sup> , Asian Development Bank <sup>119</sup> , British Medical Association Book (Birley et al) <sup>109</sup>	Protecting public health by anticipating adverse events and incorporating mitigation at the planning stages. Main focus is assessment of environmental factors.	-Checklist -Involvement of local concerns -Risk assessment
Project or programme HIA (adapted from EIA principles and processes but with a broader health focus)	Liverpool Health Impact Programme <sup>120</sup> and other UK local HIA approaches <sup>103</sup>	Improving public health by anticipating adverse health effects, and seeing opportunities to promote health at the planning stage.	- Checklist - Local concerns - Stakeholder/ expert opinion - Evidence from literature -Routine data
Economic appraisal	English Department of Health <sup>121</sup>	Economic valuation of health impacts	Expert led analysis (NB methods proposed but never implemented)
Mixed model: elements of EIA/ policy appraisal model/HIA	Swedish County Councils <sup>122</sup> , Scotland <sup>123</sup> , Greater London Authority <sup>124</sup>	Determinants of health	Assumes extensive understanding of impacts on health determinants. Swedish model uses checklist. Scottish model uses systematic comprehensive framework using range of sources

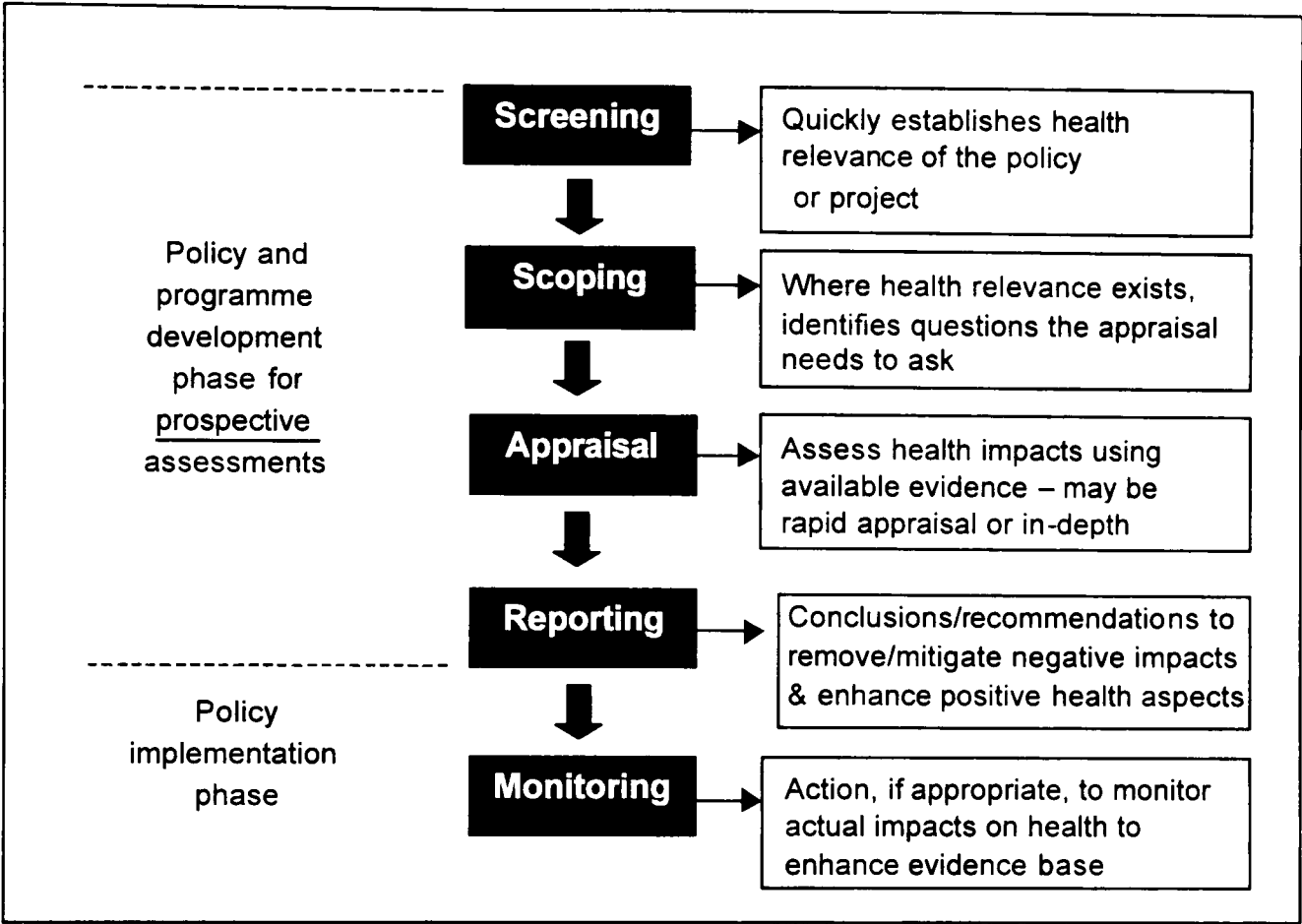
## **Models of health impact assessments of national policies**

Although there is no single universally agreed method for undertaking HIA, there is an emerging consensus on the main stages in the HIA process (Figure 2-1); the details of the stages in the HIA process and the terminology used are discussed elsewhere<sup>125 103 111 126</sup>, and are covered in chapter 10 which describes the methods developed to conduct the HIA in Slovenia.

There are now many examples of specific projects and programmes worldwide that have been subjected to HIA<sup>54 127</sup>. By contrast, there has been much less experience of the application of HIA to an over-riding national policy<sup>55</sup>. HIA of national government policy has, however, been advocated in several countries including the United Kingdom<sup>128</sup>, the Netherlands<sup>129</sup>, Canada<sup>117</sup>, New Zealand<sup>115</sup>, Australia<sup>114</sup> and Thailand<sup>130</sup>. In those countries that have applied HIA to broader policies the methods are more varied, and the stages are often less distinct than HIA methods developed for projects.

**Figure 2-1     Main stages in an ‘ideal’ health impact assessment process**

Adapted from Scott Samuel et al <sup>125</sup>, Breeze and Lock <sup>110</sup>



The Netherlands is one of the few countries to have a long standing and ongoing programme of HIA of national government policy proposals. The way in which the HIA process is organised has changed over time but the main responsibility has remained with the Department of Intersectoral Policy (a branch of the Ministry of Health originally based at the Netherlands School of Public Health) which screens policies of other ministries for potential impacts on health. It then commissions desk-based in-depth HIA of those policies that are expected to have health impacts, subject to the approval of the Ministry of Health <sup>131</sup>. Since 1996 they have conducted in-depth health impact assessments of a wide variety of policy areas including Energy Tax Regulation, the National Budget, and housing and employment policies <sup>132-134</sup>. Initially the approach was to screen all legislation going through Parliament; however, this has had to be reduced over time to make the workload more feasible, given the pace of changing government priorities.

In the UK, HIA has only been used on an ad-hoc basis at a national level to examine a few policies but there is now considerable experience at the regional government level, by the Welsh Assembly <sup>135</sup> and in London <sup>124</sup>. In the Greater London Authority, all of

the Mayoral strategies are now subject to a HIA during their development. HIAs completed so far include the strategic plan for London's future spatial development<sup>136</sup>, transport, economic development, biodiversity, air quality, municipal waste disposal, noise and culture<sup>137</sup>, with an HIA of the London Food Strategy being undertaken in spring 2006. The methods employed in London are very different from the approach taken in the Netherlands. They do not screen large numbers of policies or documents to select those that will require more in-depth work. Instead there is a clear commitment by the administration to conduct HIA only on new major (mayoral) strategies, which comprise only a small amount of the work of the Greater London Authority. In contrast to the situation in the Netherlands, the London approach also emphasizes the importance of broad stakeholder involvement in the HIA process, rather than merely being an expert-determined process.

These two examples illustrate how models of HIA have been implemented and institutionalised differently by different governments, and adapted to the particular context in which it is being applied. Further examples of how HIA has been applied in a national policy process are discussed in Chapter 13. This thesis investigates not only how to apply HIA to national food and agricultural policy, but also how the application of health 'evidence' within HIA can influence agricultural policy-making process.

### **The use of evidence in health impact assessment**

So far the most common approach to HIA has been one based on broad determinants of health<sup>54 103 125</sup>. This emphasis on health determinants means that HIAs will confront considerable uncertainty about potential health impacts. For many policies, especially those implemented at a supra-national level where even the immediate effects are often unclear<sup>138</sup>, the causal pathways are very complex, with the current evidence base patchy and often irrelevant to concrete policy options<sup>111</sup>. Methods to assemble the evidence to enable HIA to contribute to decision-making remain poorly developed<sup>111 87</sup> and often require a trade-off between speed of working and depth of analysis.

The evidence needed for HIA can differ from other forms of public health evidence in a number of ways. These include:

- the focus on complex interventions or policy proposals and their potentially diverse effects on determinants of health;



- the diversity of the sources of evidence in terms of relevant disciplines, study designs, quality criteria and sources of information because of the wide range of interventions/approaches that may contribute to improving health, (i.e. the need to search, obtain, and appraise a broad ‘evidence base’);
- the need for, but paucity of, evidence on the reversibility of adverse factors damaging to health (most evidence being of associations between factors and adverse effects, not studies that seek to reverse them);
- the broad range of stakeholders that could be involved;
- the need to seek evidence about potential unequal health impact within the population as well as on the overall effect;
- the need to apply health impact assessment within the realities of policymaking, planning and decision-making processes, which can often mean short timescales and limited resources;
- the pragmatic need to inform decision-makers even when the evidence is ‘less than perfect’.

### **Health impact assessment of food and agriculture policy**

This thesis explores how HIA, as a method of evidence-based public health research, can inform national policymaking, given the constraints that it faces. It develops and applies HIA methods to study the potential effect of incorporating the EU Common Agricultural Policy into national agricultural and food policy in the Republic of Slovenia during the process of accession to the European Union. The work presented in this thesis focuses primarily on the effects on the fruit and vegetable sector.

Agriculture and food programmes and policies worldwide are often subjected to environmental impact assessments <sup>139</sup>, but to date few published studies of HIA have been applied to agriculture, with very few at a national level. The models of HIA that have been used for these agricultural projects and policies have been very varied.

In Canada there have been two HIAs of agricultural systems, both in Quebec, as part of an integrated approach to health impact assessment, looking at ways of incorporating health within the framework of environmental assessments <sup>117</sup>. The approach is presented in a three volume manual. This includes discussion of the use of social impact assessment, epidemiology, health evaluation, economics, risk assessment and the role of health professionals. Rather than looking at overall agricultural policies, the

two published examples of agricultural HIA, hog farming and pesticide use in apple growing, have been conducted on discrete issues in single agricultural systems in response to particular public concerns. Despite the theoretical integration of methods advocated in the manual, the actual examples take a very quantitative approach, drawing on risk assessment methods and data on known health risks, and mainly focusing on the issue of environmental pollution.

This focus on traditional health risk assessment methods is rather more common than formal HIA in the agriculture sector. Risk assessment is particularly useful when there is a single specific and well-defined health risk. It has been applied extensively in the issues of food safety, for example by the United States Department of Agriculture <sup>140</sup>. The English Department of Health also conducted an assessment of risks to public health arising from the policy of disposal of animals destroyed during the 2001 foot and mouth disease outbreak <sup>141</sup>. Although this study was presented as an expert environment and health risk assessment, it took a broader approach by considering the impact of the policy on psycho-social health, similar to the approach that would be taken in a HIA. The health assessment proved to be an important tool to get other ministries to take account of wider public health issues that had not previously been considered. It contributed to changes in the animal disposal policy, leading to methods that had fewer potential health risks, and helped define characteristics of the long term environmental and health monitoring systems that will be required by other government departments. More recently the Welsh Assembly has conducted a retrospective health impact assessment of the mental health effects of the Foot and Mouth disease outbreak <sup>142</sup>. This was a more qualitative approach to HIA and focused on psycho-social and economic impacts on rural communities in Wales.

Thailand is the only low or middle-income country that has been successful at explicitly introducing HIA and applying it to the agriculture sector. The Thai government has made a commitment, as part of a programme of health system reform, to fund a research unit that conducts national HIAs under the auspices of the Minister of Public Health. It has now conducted national and regional HIAs in a range of policy sectors, including agriculture <sup>130</sup>. Many of these have been focused on infrastructure or development projects, and seek to balance the health of local communities with other policy pressures. Examples of HIAs in agriculture and rural policy include an assessment of a contract farming system and of large orange plantations where

pesticide use was a major concern. They have also started to develop HIA at a national policy level, for example, looking at the health and economic effects of sustainable agriculture.

At a trans-national level, the European Union (EU) Common Agricultural Policy (CAP) provides agricultural subsidies whose effects impact not just on Europe but world wide due to distortion of world food prices and hence trade. This has potentially adverse impacts on less developed nations <sup>143</sup>. The Swedish Institute of Public Health assessed the potential health impact of the CAP in 1996 <sup>57</sup>. It focused on broad public health effects in Europe of four CAP regimes, for dairy products, fruit and vegetables, tobacco and alcohol. Although this was entitled a health impact assessment, it did not take a recognisable HIA approach and is rather a useful descriptive review of the potential health effects of the policy sectors. The report has had very little impact in the European Commission and on CAP reform. Since it was published, the public health dimension has continued to be marginalised in CAP negotiations. Clearly, if it had been an applied HIA, it would have not been considered a success in effecting change. The Swedish Institute of Public Health has recently produced an updated analysis of the public health implications of the CAP. This is a much more detailed and critical analysis, presenting stronger evidence to support the inclusion of health considerations in CAP reform <sup>58</sup>. Although this report was prepared by the Institute of Public Health, its publication has stimulated collaboration on the health effects of the CAP between the health sector and Ministry of Agriculture in Sweden. Both of these reports should be considered as important evidence for use by policy makers in Europe even if they are not 'an HIA process' in its formally defined sense.

This review of the HIA literature was unable to identify any example of a country that has so far prospectively conducted an assessment of the health effects of incorporating the CAP into their national agricultural policy. The way in which HIA methods were developed and applied to agricultural policy in Slovenia will be described in chapter 10.

## **Conclusion**

The rise in the popularity of 'evidence- based' public health approaches, and their perceived importance in influencing policy decisions, has led to a large body of literature devoted to discussing how to synthesise and appraise research evidence.

However, the empirical basis for theories and methods that seek to make research evidence more appropriate to inform public health decision-making is less clear. In practice, methods for linking evidence to policy recommendations are less well developed than methods that have been designed for synthesising evidence.

Burden of disease analyses and health impact assessment have developed from very different theoretical and empirical bases. However, both seek to provide more relevant evidence for use by policy-makers, with both having stated aims of improving public health considerations in decision-making. This thesis will examine how these two different methods can be developed and applied to the same policy sector, to gain an understanding of how they set about achieving their goal of improving evidence-based decision-making. The second part of this thesis presents the methods and results for the burden of disease analysis due to low fruit and vegetable intake, while part three presents the methods and results of the health impact assessment of fruit and vegetable policy in Slovenia.

## **PART 2 ESTIMATING THE BURDEN OF DISEASE DUE TO LOW FRUIT AND VEGETABLE INTAKE**

## **Chapter 3 Methods of estimating fruit and vegetable consumption in the Global Burden of Disease Study**

### ***Background to nutritional risk factor analysis in the Global Burden of Disease Study***

The 1990 WHO-led Global Burden of Disease (GBD) project <sup>93</sup> was the first study to calculate the worldwide burden of disability and mortality and the contribution of different diseases and risk factors to it. In that first study the number of risk factors was limited, especially with respect to nutrition. Although it identified protein-energy malnutrition as the single greatest contributor to overall disease burden (16% of DALYs), it did not look explicitly at the impact of different elements of dietary intake <sup>102</sup>. In the second round of the GBD, which updated the findings to the year 2000, the WHO expanded the risk factors studied to include a wider range of physiological, behavioural, environmental, and socio-economic factors <sup>144</sup>. For the first time this has included diet-related risk factors including cholesterol, overweight and obesity. Although not initially included, I, together with colleagues, argued successfully for the inclusion of low fruit and vegetable consumption as a risk factor. I presented the case for including this measure at a meeting in Auckland in December 2000, having undertaken an initial literature review to demonstrate its potential importance. Its inclusion was at that time opposed by those leading the project for several reasons but, in particular, their belief that any relationships observed were attributable to unidentified confounding. Consequently, the research described in the following chapters is the first time that the global burden of disease attributable to low fruit and vegetable consumption has been estimated.

The WHO GBD project estimates the burden of disease attributable to various risk factors using the Comparative Risk Assessment method (CRA) <sup>145, 146</sup>. Two sources of information were combined to derive the burden of disease attributable to low fruit and vegetable intake; first, information on the level and distribution of consumption in the population and a baseline level of intake that would yield the lowest overall population risk; second, estimates of the association (relative risks) between fruit and vegetable intake and selected health outcomes. Data on both risk factor levels and relative risks were obtained for both genders, 8 age groups (in years: 0-4, 5-14, 15-29, 30-44, 45-59, 60-69, 70-79, 80+), and 14 geographical regions (Table 3-1)

The regional classification used by WHO in the GBD study, and adopted for this research has no official status and is for analytical purposes only. Countries were divided into five mortality strata on the basis of their levels of child mortality under five years of age and 15-59-year-old male mortality: A. Very low child mortality and very low adult mortality; B. Low child mortality and low adult mortality; C. Low child mortality and high adult mortality; D. High child mortality and high adult mortality; and E. High child mortality and very high adult mortality. These mortality strata were then applied to the six main WHO regions (African Region, Region of the Americas, Eastern Mediterranean Region, European Region, South-East Asia Region, and Western Pacific Region) to produce the 14 epidemiological sub-regions (Table 3-1). This is discussed further in chapter 8.

**Table 3-1 Countries and standard regions use in Global Burden of Disease study**

Region	Country
AFR D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo
AFR E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
AMR A	Canada, Cuba, United States of America
AMR B	Antigua and Barbuda, Argentina, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela
AMR D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
EMR B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, Kuwait, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
EMR D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen
EUR A	Andorra, Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, United Kingdom
EUR B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Bulgaria, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The Former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, Yugoslavia
EUR C	Belarus, Estonia, Hungary, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russian Federation, Ukraine
SEAR B	Indonesia, Sri Lanka, Thailand
SEAR D	Bangladesh, Bhutan, Democratic People's Republic of Korea, India, Maldives, Myanmar, Nepal
WPR A	Australia, Brunei Darussalam, Japan, New Zealand, Singapore
WPR B	Cambodia, China, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam

A: very low child mortality and very low adult mortality;

B: low child mortality and low adult mortality;

C: low child mortality and high adult mortality;

D: high child mortality and high adult mortality;

E: high child mortality and very high adult mortality.

High-mortality developing sub-regions: AFR-D, AFR-E, AMR-D, EMR-D, SEAR-D.

Low-mortality developing sub-regions: AMR-B, EMR-B, SEAR-B, WPR-B.

Developed sub-regions: AMR-A, EUR-A, EUR-B, EUR-C and WPR-A.



## ***Estimating fruit and vegetable consumption worldwide***

The rest of this chapter describes the research methods devised to estimate fruit and vegetable consumption worldwide for the burden of disease analysis, and discusses the methodological constraints.

### **Defining fruit and vegetable intake as a risk factor**

In this study, the risk factor was an aggregate measure designated 'fruit and vegetable intake' which is defined as being total fruit and vegetable consumption, including fruit and vegetable juices but excluding potatoes, pulses and starchy vegetables as this is consistent with current international recommendations <sup>147, 13, 12</sup>. Intake was treated as a continuous variable and expressed in grams per person per day.

### **Criteria for considering sources of data on fruit and vegetable intake**

#### **Potential sources of data on intake and supply**

Data on dietary intake and supply of fruit and vegetables may be available at the national, household, and individual level. The following sub-sections briefly describe these potential sources of information and the extent to which they were used for the study.

#### ***I: National level***

The most commonly-used source of information at the national level is data from food balance sheets, published by the Food and Agriculture Organization of the United Nations (FAO) for 176 countries <sup>50, 148</sup>. Food balance sheets provide standardized estimates of the average amount of food available per person on a daily basis. They are calculated by estimating the quantity of food produced in a given country added to the quantity of food imported (adjusted for changes in stocks), and subtracting the food exported, lost in storage and transport, fed to livestock, or used for non-dietary purposes, with some adjustment for wastage. The estimated national food supply is then divided by estimated population size to derive per capita figures (in kg per person per year). The main limitation of food balance statistics is that they tend to reflect national food availability patterns rather than actual dietary intake and are thus a reflection of both intake and wastage at the household level. As a result, they cannot provide information on the dietary intake of different population sub-groups and they tend to overestimate food consumption, particularly in developed countries. However,

time trends in food availability tend to parallel those reported in household surveys <sup>149</sup> so FAO food balance sheets constitute a useful tool for international comparisons.

## ***II: Household level***

Household-based surveys, where the unit of measurement is the household rather than the individual, are undertaken to explore the diversity of food consumption patterns among communities. They can give information about dietary patterns among different groups, making distinctions between geographical sub-regions, income categories and family types. The most frequently used methods to collect data are the food account method, the inventory method, the household food record method, and the list-recall method <sup>150</sup>. Household surveys have several limitations: they cannot provide information on individuals; they are subject to sampling errors; they sometimes exclude foods consumed outside the home or certain food groups (e.g. sweets, alcoholic beverages, etc.); and some methods are subject to recall bias. In addition, they are available for only a limited number of countries and the diversity of the methods used make international comparisons difficult. Due to these limitations, data from household surveys were not used in this research.

## ***III: Individual level***

It is generally agreed that there is a marked lack of internationally comparable data at an individual level. This is partly due to the difficulties associated with measuring the dietary intake of individuals, including potential measurement error and bias. In spite of this, data collected at the individual level provide invaluable information on the mean dietary intakes of population sub-groups (e.g. stratified by age and sex) and variability in intakes. They are thus essential if intake estimates are to be stratified (necessary for the GBD methodology).

Data on present or recent food consumption are collected using four main techniques: (1) the 24-hour recall; (2) food records (with or without weighing of foods); (3) food frequency questionnaires; (4) food history. Details of these methods and their limitations can be found elsewhere <sup>150 151</sup>. The choice of method to collect data at the individual level will normally depend on the objectives of the study and on the resources available. When the main objective is to obtain the mean consumption of a group of individuals, it is generally sufficient to use a single 24-hour recall or a one-day food record. This approach is often used in large national surveys of dietary intake as it

represents a relatively small burden for the respondents and is associated with relatively low costs. The main caveat in using information covering only one day is that it tends to increase artificially the standard deviation of the estimates due to high day-to-day variation. Thus, the observed distribution of intakes has extreme values that are higher and lower than any of the true long-term averages for any individual. Including several days of data collection for each respondent will normally dampen day-to-day variation but it will also increase the burden on the respondents and the costs. If the objective of the study is to assess the distribution of food consumption in a group or the position of an individual's intake within the population, more complex methods such as repeated 24-hour recalls or food records, food frequency questionnaires (FFQ), or dietary history are needed. These approaches have been used mostly in cohort studies or smaller, more focused surveys of dietary intake; they have less frequently been used in national surveys of dietary intake.

### **Sources of data used**

Only dietary surveys with data collected at the individual level can provide information on mean intakes and variability in intakes in population subgroups. Thus, this source of information was used as the “gold standard”. The initial aim was to identify data from at least one valid and representative population-based survey of dietary intake for each of the 191 countries covered by the GBD.

This was not however possible as currently only a few countries (mainly economically developed) have conducted representative national or sub-regional surveys of dietary intake at the individual level, while a few others have performed surveys in selected sections of the population only. Conversely, for the majority of countries in the world, yearly estimates of available food supply exist only in the form of the FAO Food Balance Sheets. These food balance sheets were used to complement data collected at the individual level, when required. The methods used and the sub-regions to which they were applied are described below.

### ***Criteria for including sources of individual level data***

The main criteria used for including sources of individual level data of fruit and vegetable intake were as follows:

- Time frame: The study was relatively recent—defined as having been performed since 1980;

- Study sample: The reference population was described and the sample was representative of this population;
- The sampling strategy was documented and was as close as possible to random sampling;
- The sample size was large (sample size calculation ideally included) with as wide an age range as possible was included;
- The level of non-response was documented;
- Study design: Only population-based cross-sectional studies, baseline assessment of large cohort studies (sample representative of the general population), or large interventions (sample representative of the general population) were considered for inclusion. Case-control studies were excluded from the selection process;
- Validity of the methods: The methods used to collect data were as free of bias as possible;
- Data were collected at the level of the individual;
- The statistical analysis of the data was appropriate;
- Type of dietary information: Data on fruit and vegetable intake had to be available as grams per day and not as frequencies (e.g. <1 serving a day, 1–2 servings a day, every day, etc.).

### ***Search strategy for the identification of dietary intake data***

Dietary intake data were identified using a comprehensive worldwide search which included computerized databases of published articles, library catalogues, hand-searching of bibliographies, an internet search of possible sources of data, and extensive contact with experts in the field, national governments, and nongovernmental organizations.

### **Computerized databases and library search**

I used the following computerized sources of information in the search process: Medline, CAB abstracts, and Embase. MESH terms used to search in Medline and HealthStar included “Fruit”, “Vegetables”, “Nutrition-Surveys”, “Diet-Surveys”, and “Food-Habits” (each term included all subheadings). Similar search terms were used in the other databases but adapted to the specific database search facilities. The search was restricted to human studies published in all languages since 1980.

I rejected articles on initial screen if it was possible to determine from the title and abstract that the article did not provide estimates of fruit and vegetable intake of a population or did not report data from a representative population-based survey of dietary intake. When a title or abstract could not be rejected with certainty, the full text of the article was obtained for further evaluation. Citation lists in the articles retrieved were reviewed. Random checks were performed by a second reviewer .

The following catalogues were searched for other publications and conference proceedings that could provide appropriate data: the University of London; the British Library; the former Resource Centre of the Public Health Nutrition Unit at the London School of Hygiene and Tropical Medicine; libraries at the UN Food and Agriculture Organization (FAO), Rome and the Ministry of Agriculture, Food and Fisheries (MAFF) in the United Kingdom. Citation lists in the documents retrieved were reviewed.

### **Internet searches**

Internet searches (using “Google” search engine—<http://www.google.com>) had two objectives: to locate original sources of food intake data available on the internet, and to identify national and international organizations that could identify possible data sources including academic departments of nutrition or dietetics, food and nutrition agencies, and ministries of health.

Messages requesting help in identifying data sources were also posted to four scientific mailing lists: (1) [NUTEPI@listserv.gmd.de](mailto:NUTEPI@listserv.gmd.de) (nutritional epidemiology); (2) [food-for-thought@jiscmail.ac.uk](mailto:food-for-thought@jiscmail.ac.uk) (nutrition); (3) [public-health@jiscmail.ac.uk](mailto:public-health@jiscmail.ac.uk) (public health); and (4) [epidemio-1@cc.umontreal.ca](mailto:epidemio-1@cc.umontreal.ca) (epidemiology).

### **Contacts with experts**

Numerous direct contacts were made with WHO Regional Nutrition Advisers and other experts, seeking references to published or unpublished data sources or for the identification of appropriate contact persons. Experts were defined as corresponding authors of large population-based studies of dietary intake, or contact persons in governmental agencies or country-specific nutrition organizations (this included existing networks involving the WHO, the International Obesity Task Force, and other international nutritional networks).

## ***Methods for obtaining estimates of national intake***

### **Methods used where more than one data source exists**

The following hierarchy of data quality was used to select one source of data for a given country where more than one data source was available:

- national survey of individual dietary intake;
- large sample survey of good quality—its quality being assessed from its general design, method of data collection (appropriate method applied adequately, ideally with data collected prospectively), potential sources of bias (limited), and generalisability (representative sample of the population surveyed); and
- small sample survey of good quality—its quality being assessed as discussed above.

### **Methods for obtaining estimates where no data source exists**

#### **I: Data on mean intakes not available for some age or sex groups**

Attempts were made to contact the original investigators to obtain data disaggregated into the required age categories. However, this was not always possible and so indirect estimates were made using the following approaches.

#### **II: Data not available for children**

Few of the available dietary intake surveys contained data from children under 18 years. To extrapolate intakes of children, two sources of information were used.

Published estimates on energy requirements for infants and children <sup>147</sup> suggested that girls and boys aged 5–14 years require approximately 15% and 20% less dietary energy than adult women and men respectively. The figures for girls and boys aged 0–4 years are about 40% and 50% less than adults of the same sex respectively. These estimates may, however, vary among countries and they will depend on the true energy expenditure of the children.

Using data from the surveys collected for this study, it was estimated that boys and girls aged 5–14 and those aged 0–4 years consume, respectively, about 20% and 45% less fruit and vegetables than adults aged 30–59 years.

On the assumption that fruit and vegetable consumption decreases proportionally with energy intake in children compared with adults, the two sources of information tend to agree. Thus, the following adjustment factors were used:

- Children 5–14 years: 20% lower fruit and vegetable intake than adults aged 30–59.
- Children 0–4 years: 45% lower fruit and vegetable intake than adults aged 30–59.

### **III: Data not available for the elderly**

Many surveys only included adults up to age 60–65 years. Once again, published estimates of energy requirements <sup>147</sup> and available survey data on fruit and vegetable intakes were used to derive an adjustment factor. Figures based on energy requirements suggest that men and women in older age groups consume approximately 10–15% less energy than middle-aged adults.

Information on fruit and vegetable intakes from survey data (collected for this research) indicate that men and women aged 70–79 years consume approximately the same amount of fruit and vegetables daily, on average, as their counterparts aged 30–59 years, while individuals aged 80 years and over consume approximately 10% less fruit and vegetables than middle-aged adults.

Based on these observations, the following assumptions were made.

- Individuals aged 70–79 years consume the same amount of fruit and vegetables as individuals in the closest age group (60–69 years).
- Individuals aged 80+ years consume 10% less fruit and vegetables than those aged 30–59 years.
- However, when the resulting estimates were greater than the reported intakes of survey participants aged 70–79, a different approach was taken: it was assumed that individuals aged 80+ years had an intake of fruit and vegetables similar to the intake observed in the 70–79 age group.

### **IV: Surveys where the age groups did not correspond to the GBD age groups**

In these cases, the results available for the most similar age categories (greatest overlap of ages) were applied, weighing for population sizes when necessary.

### **V: Data on mean intakes available for only one gender or for males and females taken together**

In the case of Mexico, adult data were available only for women. In the case of France, only the overall mean intakes by age group (males and females taken together were available) were accessible. Using data available from the surveys obtained, it was estimated that, on average, males consume approximately only 1% more fruit and

vegetables than females. It was thus assumed that Mexican and French males consume similar amounts of fruit and vegetables to their female counterparts.

#### **VI: Data on standard deviations not available**

In some cases, survey information did not include calculations of standard deviations although these were necessary for the GBD methodology. The authors of the studies were contacted and, in some countries, the required figures were provided. When this was not possible, the following assumptions were made:

- When standard deviations were missing for one or more age groups and for one or more countries within a sub-region (usually for children or the elderly), data were pooled, based on the information available (all countries with information for these age groups).
- When standard deviations for all age groups were missing for a country, the standard deviations of the country within the same sub-region displaying the most similar mean intakes and method of data collection were applied. For example, for the United Kingdom, the standard deviations from Germany were used.

However, since data on sample size are required for the estimation of the pooled standard deviation (and its confidence interval), pooled estimates were based only on the information available from the surveys. The following sections describe the assumptions and extrapolations that were made.

#### **VII: Data on standard deviation and sample size not available for all countries in a sub-region**

For two sub-regions (SEAR-D and EMR-B) the survey data available included only mean intakes. As a result, it was not possible to extrapolate standard deviations from other countries within the same sub-region. Thus, the pooled standard deviations of the sub-region displaying the closest sub-regional mean intakes were applied (EUR-C for SEAR-D and EUR-B for EMR-B).

Another approach to the extrapolation of missing standard deviations could have been to use the standard deviations of a sub-region that is close geographically, that has similar economic characteristics, and for which data were available. With SEAR-D, for example, a possible choice may have been to use the standard deviations of WPR-B. However, as the standard deviations obtained for WPR-B are smaller than those of EUR-C, it was decided to opt for an approach that used the larger standard deviation,



hence the choice of EUR-C. For EMR-B, there was no obvious choice among the sub-regions for which data were available and thus the standard deviations of EUR-B were retained.

### **VIII: Data on mean intakes unavailable for a sub-region**

When survey data were unavailable for all countries within a sub-region, it was originally planned to apply the results obtained for another sub-region displaying the most similar fruit and vegetable availability (from FAO Food Balance Sheets information) and demographic and health characteristics (using data from the World Health Report 2000 <sup>95</sup>, the World Bank classification of economies based on gross national product <sup>152</sup>, and the CIA World Factbook <sup>153</sup>).

The dietary patterns of the African country groupings (AFR-D and AFR-E), and of the EMR-D, SEAR-B, and AMR-D groupings are too different from those in the other GBD sub-regions to allow for valid extrapolation.

As an alternative approach, FAO food balance sheet data were combined with survey information to obtain FAO-derived proxy mean intakes by age group and sex for the five sub-regions for which no individual survey data were identified (as described in the following section). This approach was likely to provide more valid estimates of mean sub-regional fruit and vegetable intakes than extrapolations from other sub-regions, as the basis of the calculations was information collected directly from within each country within the sub-region.

### ***Methods for estimating FAO-derived proxy mean intakes***

Country-specific data on availability of fruit (excluding wine) and vegetables (excluding potatoes) and estimates of population size were downloaded from the FAOstat database on the FAO internet website for the appropriate time-frame <sup>154</sup>. Three-year averages (1996–1998) were calculated in order to reduce the effect of yearly variations. These data were then used to calculate sub-regional population-weighted average fruit and vegetable availability in grams per person per day. For seven relatively small countries, no estimates were available (Bahrain, Bhutan, Equatorial Guinea, Oman, Qatar, Samoa, Singapore). Estimates of sub-regional food availability (1996–1998) are listed in Table 3-2.

**Table 3-2      Fruit and vegetable availability by GBD sub-region**  
**(1996–98 average)**

Sub-region with no available survey data	Fruit and vegetable availability (grams/person.day)
AFR-D	291
AFR-E	194
AMR-D	317
EMR-D	323
SEAR-B	205

Source: FAOstat Food Balance Sheets Statistics 2001

**What differences are found when comparing data from food balance sheets and dietary surveys?**

As mentioned earlier, food balance sheets provide information on the amounts of foods available for consumers and are thus a reflection of both intake and waste at the household level. Although food supply statistics are commonly used in ecological studies of diet and disease, little information is available on how they actually compare with reported intakes of foods. It has been reported that the balance sheets tend to overestimate intakes in developed market economies <sup>18</sup>. In developing countries, such as those included in the five sub-regions for which no survey data were obtained <sup>152</sup>, it has been suggested that food balance sheets are likely to underestimate food availability as they do not take account of food grown for home consumption or wild food collected. However, few studies have tested this hypothesis. In Nepal and Pakistan, the average energy consumption from intake surveys was found to be about 10% higher than that from FAO food balance sheets <sup>155 156</sup>.

Using survey data obtained for this project, a comparison was made between fruit and vegetable availability from FAO availability statistics and estimates of national mean intakes derived from national food consumption surveys. For each country, mean national supply, based on at least 3 years of FAO data, was calculated. National estimates of mean fruit and vegetable intakes were derived from population-based surveys from fifteen countries, gathered for this study. For each country, the FAO:survey estimate ratio was calculated. This ratio ranged from 0.93 to 2.70 (median value=1.39). Although there was a tendency for FAO data to overestimate intakes (fourteen out of fifteen countries), the degree of overestimation varied greatly among the countries included in this study (5-270 %) <sup>157</sup>. As food supply statistics are the only

source of information on dietary patterns in most countries of the world, further information on how they reflect food intakes is needed. In view of these contradictory results and because of the lack of further available information, no correction factor was applied to the FAO estimates in the calculations of the FAO-derived proxy mean intakes for the five sub-regions with no available survey data.

**Estimating age-sex distributions for FAO-derived proxy mean intakes**

As food balance sheets do not provide information on food intake by sex and age group, an attempt was then made to estimate how the total availability of fruit and vegetables in a sub-region would be distributed among the different sex and age groups. To achieve this objective, a two-step process was used.

The proportion of total fruit and vegetable intake consumed by the different age/sex groups for each sub-region with available survey data was estimated. As expected, the distributions of intakes were strongly influenced by the population structures of the sub-regions.

For each of AFR-D, AFR-E, AMR-D, EMR-D, and SEAR-B, the calculated distributions of intakes (Step 1) of the sub-region displaying the most similar population structure (Table 3-3) was applied to the FAO availability data. As a result, FAO-derived proxy mean intakes by age and sex were obtained.

**Table 3-3      Details of sub-regional extrapolation of age–sex intake distribution for sub-regions where no survey data were available**

Sub-region with no available survey data	Distribution of intakes extrapolated from
AFR-D	EMR-B
AFR-E	EMR-B
AMR-D	EMR-B
EMR-D	EMR-B
SEAR-B	SEAR-D

**Obtaining standard deviation estimates for FAO-derived proxy mean intakes**

In order to obtain estimates of standard deviations when FAO-derived proxy mean intakes were used, the following approach was used. Proxy intakes were compared with all other sub-regional mean intakes. The standard deviations of the sub-region

displaying the most similar sub-regional intakes and closest level of socioeconomic development were then applied to AFR-D, AFR-E, AMR-D, EMR-D and SEAR-D, (Table 3-4).

**Table 3-4      Details of sub-regional extrapolation of standard deviations for sub-regions where no survey data was available**

Sub-region using FAO-derived proxy intake estimates	Sub-region from which standard deviations were extrapolated
AFR-D	EMR-D
AFR-E	SEAR-D
AMR-D	EMR-B
EMR-D	EMR-B
SEAR-B	SEAR-D

***Description of intake survey data included***

Details of the 26 studies from which survey data were available and which are included in this project are described in Table 3-5. The proportion of the sub-regional population covered by these countries is given in Table 3-6. This proportion is generally high or acceptable except for two sub-regions (EMR-B = 1.4%; EUR-B = 3.8%).

Twenty-two of the surveys were national. For Argentina, a compilation of small representative surveys was provided—these cover the majority of the country. All but two studies were from the 1990s. Most surveys used information from one 24-hour dietary recall or food diary. Other methods of data collection included multiple 24-hour recalls, 7-day weighed food records, food-frequency questionnaire, and food history. The majority of the surveys attempted to provide nationally representative samples, most using stratified random sampling. Sample sizes ranged from about 1000 people (Argentina) to over 22 000 (Belgium).

**Characteristics of excluded studies**

Due to the paucity of available information on fruit and vegetable intake at the individual level, few studies were excluded. Reasons for exclusion included the following:

- Another source of data was used for the country (e.g. more representative sample of the population or better method of data collection);
- The amounts consumed in grams per day could not be derived from the survey;
- The data were not representative of the population of the country.

**Table 3-5 Details of the dietary intake studies used**

Sub-region	Country	Contact/Reference	Name of survey (if any)	Sample	Dietary data collection method	Year	Sample size	Sex	Age range	Limitation
AMR-A	United States of America	<sup>158</sup> , <sup>159</sup>	USDA Continuing Survey of Food Intakes of Individuals	Nationally representative sample	Two 24-hr dietary recall—non-consecutive days	1994–96	4 806	MF	25–75yrs	
AMR-B	Argentina	<sup>160</sup>	Collection of various dietary surveys in Argentina	Random samples in Greater Buenos Aires, Province of Buenos Aires, West Areas (Mendoza).	7-day records	1999–2000	1 068	MF	0+ yrs	Collection of several small surveys. Very small sample size in 60+ yrs excluded (n = 35). In West Areas (Salta), recruitment through a nutrition program
	Mexico	<sup>161</sup>	National Nutrition Survey	Representative sample of 21 000 families	Not known	2000	2 646	F	12–49yrs	No data on adult males. Data on children not provided.
EMR-B	Kuwait	<sup>162</sup>	Kuwait Total Diet Study	Not known	Not known		Not known	MF	0+ yrs	No SD
EUR-A	Belgium	<sup>163</sup>	Belgian Interuniversity Research on Nutrition and Health	Random sample from voting lists in 42 out of 43 Belgian Districts	One 24-hr recall	1980–84	22 224	MF	25–74 yrs	
	Denmark	<sup>164</sup>	Dietary habits in Denmark	Random sample from Central Population register	7-day food record	1995	3 098	MF	1–79 yrs	
	Finland	<sup>165</sup>	Dietary Survey of Finnish Adults	Random sample (age stratified), cross-sectional-5 sub-regions	One 24-hr recall	1997	3 153	MF	25–74 yrs	
	France	<sup>166</sup>	INCA: Enquête Individuelle et Nationale sur les Consommations Alimentaires	Representative national sample	7-day food record	1998-99	3 003	MF	3+ yrs	Means for males and females jointly No SD/ sample size
	Germany	<sup>167</sup>	German Nutrition Survey	Representative national sample	Dietary history	1998	4 030	MF	18–79 yrs	
	Ireland	<sup>168</sup>	National Health and Lifestyle Survey	2 stage sampling using Irish Electoral register	Semi-quantitative food-frequency questionnaire	1998	6 332	MF	18+ yrs	

/ continued ...

**Table 3-5 (continued) Details of the dietary intake studies used**

Sub-region	Country	Contact/Reference	Name of survey (if any)	Sample	Dietary data collection method	Year	Sample size	Sex	Age range	Limitation
EUR-A (contd)	Israel	169	First National Health and Nutrition Survey	Representative national sample	24-hr recall (in 50% 2 recalls)	1999–2001	1 963	MF	25–64yrs	
	Italy	170	INN-CA – Nation-wide Nutritional Survey of Food Behaviour of the Italian Population	Multistage random sample of households with sub-regional stratification	7-day food diaries	1994–96	2 734	MF	0+ yrs	
	Norway	171	National Dietary Survey	Representative random sample of the population	Self-administered food-frequency questionnaire	1997	4 465	MF	16–79yrs	
	United Kingdom	172-175	National Diet and Nutrition Survey (4 surveys)	Nationally representative random sample from postcode address files	7-day weighed record (4-days for under 5 yrs)	1986–2000 4 surveys	Each survey ~2 000	MF	1.5–4.5/ 4–18 / 16–64 / >65 yrs	No SD for combined fruit and vegetable intake, not correct age categories
EUR-B	Bulgaria	176	National Dietary and Nutritional Survey of the popn of Bulgaria	Nationally representative quota sample	24 hr estimated consumption	1998	2 800	MF	1– >75 yrs	
EUR-C	Estonia	177	Baltic Nutrition Survey	Random sample from the National Population Register	One 24-hr recall	1997	2 108	MF	18–65 yrs	
	Kazakhstan	178	National survey of the state of nutrition in the Republic of Kazakhstan	Nationally representative random sample	One 24-hr recall	1996	3 480	MF	15–80 yrs	
	Latvia	177	Baltic Nutrition Survey	Random sample from the National Population Register	One 24-hr recall	1997	2 308	MF	18–65 yrs	
	Lithuania	177	Baltic Nutrition Survey	Random sample from the National Population Register	One 24-hr recall	1997	2 153	MF	18–65 yrs	

**Table 3-5 (continued) Details of the dietary intake studies used**

Sub-region	Country	Contact/Reference	Name of survey (if any)	Sample	Dietary data collection method	Year	Sample size	Sex	Age range	Limitation
	Russian Federation	179	Russian Longitudinal Monitoring Survey	Multistage probability sample	One 24-hr recall	1998	9 593	MF	0+ yrs	No SD
SEAR-D	Bangladesh	180	Nutrition Survey of Rural Bangladesh	Two stage systematic sampling for study locations, and random sampling of households	One 24-h weighed record by trained dietary investigator	1981–1982	4 904	MF	1–70+ yrs	No SD, different age categories
	India	181	National Nutrition Monitoring Bureau surveys (1994) and District Nutrition Profiles (1995-6)	Varied survey designs	One 24-hr recall	1994–96	Compiled surveys of 18 states, 4 sub-regions	MF	1–18+ yrs	No SD, different age categories
WPR-A	Australia	182	National Dietary Survey in Australia	Multi-stage sample with quota	One 24-hr recall	1995–96	13 858	MF	2+ yrs	
	Japan	183-185	National Nutrition Survey	Cross-sectional Nationwide survey	Semi-weighed 1-day food record	1995	14 240	MF	1+ yrs	
	Singapore	186	National Nutrition Survey	Random sample	Food frequency questionnaire	1998	2 388	MF	18–69 yrs	
WPR-B	China	187	China Health and Nutrition Survey	Multistage random cluster sampling	3 contiguous 24-hr recall	1997	12 194	MF	0+ yrs	

F      female                      M      male

**Table 3-6      Proportion of sub-regional population for which survey data were obtained**

Sub-region	% of sub-regional population <sup>a</sup>
AFR-D	–
AFR-E	–
AMR-A	87.5
AMR-B	32.0
AMR-D	–
EMR-B	1.4
EMR-D	–
EUR-A	71.3
EUR-B	3.8
EUR-C	69.2
SEAR-B	–
SEAR-D	93.7
WPR-A	97.6
WPR-B	84.0

**Obtaining sub-regional estimates from dietary survey data**

The following approach was used to obtain sub-regional estimates of fruit and vegetable intake using available data from individual dietary surveys.

**Obtaining estimates for sub-regions where data is available for two or more countries**

In order to obtain sub-regional means and standard deviations (and thus to obtain 95% confidence intervals for these estimates) when data were available for two or more countries within a sub-region, means and standard deviations were pooled. The methods used are shown in Figure 3-1. It is assumed that each sub-region is a stratified sample, with the strata being countries. Because of the lack of information on the shape of the distributions of intakes, it was also assumed that intakes follow a normal distribution (this assumption is discussed in more detail in the following section).

It is important to note that if there is substantial heterogeneity among countries in a sub-region these methods will tend to underestimate the true standard error of the pooled mean and pooled standard deviation. In addition, pooling includes only a few countries within a sub-region. It was thus assumed that the pooled sub-regional mean intake and standard deviation are representative of the true estimates and that differences between the pooled estimates and errors due to non-availability of data



would cancel each other out. Finally, using data from only a few countries may underestimate the true variation of intakes within a sub-region. However, for most sub-regions with available data, a large proportion of the total sub-regional population was covered by the surveys (Table 3-6).

**Figure 3-1     Estimating the sub-regional mean intake**

Estimation of the sub-regional (pooled) mean:

$$\hat{\mu} = \frac{\sum N_i \bar{x}_i}{\sum N_i} \text{ where } i=1, \dots, k \text{ sampled countries, } N_i \text{ is the population of the } i\text{th country and } \bar{x}_i \text{ is the mean of the } i\text{th country.}$$

95% confidence interval (CI) for this estimator:

The variance of this estimator can be derived using:

$$\begin{aligned} Var(\hat{\mu}) &= \left(\frac{1}{\sum N_i}\right)^2 Var(\sum N_i \bar{x}_i) \\ &\text{and assuming the means are independent} \\ &= \left(\frac{1}{\sum N_i}\right)^2 \sum Var(N_i \bar{x}_i) = \left(\frac{1}{\sum N_i}\right)^2 \sum N_i^2 Var(\bar{x}_i) \end{aligned}$$

Where now:

$$Var(\bar{x}_i) = \frac{s_i^2}{n_i} \left(1 - \frac{n_i}{N_i}\right), \text{ with } s_i \text{ the standard deviation for the } i\text{th country, sample size } n_i.$$

The term  $\left(1 - \frac{n_i}{N_i}\right)$  is the finite population correction.

The standard error of the estimator is the square root of the variance.

The 95% CI for the sub-regional (pooled) mean is calculated as:

$$= \text{Sub-regional mean} \pm (1.96 \times \text{standard error of this estimator})$$

Estimating the sub-regional standard deviation

Estimation of the sub-regional (pooled) variance and standard deviation:

$$\hat{\sigma}^2 = \frac{\sum N_i s_i^2}{\sum N_i} = \hat{\sigma}^2 = \frac{\sum N_i s_i^2}{N}$$

where  $\sigma^2$  =pooled variance for the sub-region,  $i=1, \dots, k$  sampled countries,  $N_i$  is the population of the  $i$ th country and  $s_i^2$  is the variance (square of SD) of the  $i$ th country;  $N$  is the sum of the  $N_i$ , in other words the sum of the populations of the sampled countries. This is unbiased because the expected value of a sample country's variance is the sub-regional variance, i.e.  $E(s_i^2) = \sigma^2$ ,

- then  $E(\hat{\sigma}^2) = \frac{1}{N} \sum N_i E(s_i^2) = \frac{1}{N} \sigma^2 \sum N_i = \sigma^2$

- 95% CI for this estimator:

The 95% CI for the sub-regional (pooled) variance ( $\hat{\sigma}^2$ ) is approximated using:

- LowerCI = Sub-regional variance\*  $(n-1) / \chi^2(n-1, 0.025)$
- UpperCI = Sub-regional variance\*  $(n-1) / \chi^2(n-1, 0.975)$

where  $n = (\sum n_i)$  and  $n_i$  is the sample size for the  $i$ th country:  $n$  is thus the total size of the sample taken from the sub-region.

### **Obtaining estimates for sub-regions where data is available for only one country**

In four country groupings (AMR-A, EMR-B, EUR-B, and WPR-B), only one source of intake data was available. For AMR-A and WPR-B, the surveys were conducted in the United States and China, respectively. As these countries represent 84–88% of the total sub-regional population (Table 3-1), it was assumed that intake data from these countries were representative of sub-regional intakes. For EMR-B and EUR-B, however, the surveys were conducted in countries that represented only a very small proportion of the total sub-regional population (1.4% and 3.8% respectively). For this reason, a different approach based on pooling survey and FAO food balance sheet data was used.

EMR-B: First, FAO-derived proxy mean intakes for the sub-region were calculated using the method described above (when no survey data were available for a sub-region). The sub-regional fruit and vegetable supply in AMR-A is the closest to that observed in EMR-B. It was assumed that the sex/age sub-regional distribution of intakes was similar to that observed in Kuwait. Second, the FAO-derived proxy mean intakes were pooled with intake data from Kuwait to obtain mean intakes for EMR-B.

EUR-B: First, FAO-derived proxy mean intake for the sub-region was calculated. It was assumed that the distribution of intakes among sex/age groups was similar to that observed in Bulgaria. Second, the FAO-derived mean proxy intakes were pooled with intake data from Bulgaria to obtain pooled mean intakes for EUR-B.

### ***Results of estimates of fruit and vegetable intake by sub-region, age and sex categories***

Estimates of fruit and vegetable intakes stratified by sub-region, age and sex are given in Table 3-7 and Table 3-8. Results are presented as means, with 95% CI for the mean, and as standard deviations with 95% CI for the standard deviation.

Estimates of fruit and vegetable intakes were highest in EUR-A, followed by WPR-A. In these sub-regions, it is possible that reported consumption could have been inflated by conscious (social desirability bias) or unconscious over-reporting of fruit and vegetable intake by the survey respondents <sup>188</sup>. The reported intakes in some countries within these sub-regions are greater than expected. This is particularly the case for the United Kingdom and Germany where the estimated mean national fruit and vegetable consumption was higher than in Mediterranean countries such as Italy and Israel. It is possible that recent public health campaigns, such as those that took place in Finland <sup>189</sup>, coupled with changes in the retail trade, and thus in marketing and distribution of fruit and vegetables, have improved the dietary habits and increased the fruit and vegetable intake of these populations. This would be consistent with the striking improvements in cardiovascular mortality in these populations. Conversely, it is possible that the inclusion of fruit juices in the estimates of fruit and vegetable intakes made the estimates appear larger than expected. Surprisingly, reported intakes in AMR-A—the other highly economically developed sub-region—are on average only 74–82% of those observed in the EUR-A and WPR-A. The lowest intakes were found in AMR-B, in EUR-C, SEAR-B, SEAR-D, and AFR-E.

As expected, intakes varied by age group, with children and the elderly generally having lower intakes than middle-aged adults. However, in a few sub-regions our calculations yielded higher intakes for elderly individuals than younger adults. This was the case particularly for AFR-E, AFR-D, and EMR-D, three groupings where FAO-derived proxy mean intakes were calculated using the distribution of total intakes from another grouping with available data. Because the true age/sex distribution in AFR-E, AFR-D and EMR-D is slightly different from that of the chosen proxy

grouping, the calculation of mean intake within each age–sex strata and the balance among strata was affected. This is observed particularly in the smaller age strata (especially among elderly people in these sub-regions). As a result, the FAO-proxy mean intakes are less reliable in population strata with smaller sample sizes and must be interpreted with caution.

Pooled standard deviation estimates were available from only seven groupings (AMR-A, AMR-B, EUR-A, EUR-B, EUR-C, WPR-A, and WPR-B). For the other sub-regions, data were applied from the sub-region displaying the most similar intakes by age and sex, and when appropriate, method of data collection. These extrapolations need to be regarded with caution, as the standard deviations of one sub-region may not represent well the standard deviations of another sub-region despite similarity in overall mean intakes. The results shown in Table 3-8 indicate that standard deviations varied considerably by sub-region, sex and age group, with an overall median standard deviation of 223 g/day. Estimates tended to be lower in females than in males on average (but with variations by age group), and they were generally lower in young children. In some sub-regions, standard deviations were also slightly smaller in the elderly.

It is assumed that the reported fruit and vegetable intakes are normally distributed, due to the lack of available information on the skewness of the distributions, except for the United States where dietary intakes are typically skewed towards higher values <sup>190</sup>. However there was no empirical basis to expect skewness to apply to any other country. The alternative, assuming a normal distribution, creates the problem that some individuals will be recorded as having negative consumption. As this is impossible, the normal distribution has been truncated at zero, with all those falling below this value allocated a value of zero. The results of a sensitivity analysis, described below, based on data from the United States suggest that the approach used is likely to be conservative.

**Table 3-7      Mean intake of fruits and vegetables by sub-region, age and sex  
(grams per person per day)**

Sub-region	Sex	Age Group (years)							
		0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
AFR-D	Male	144 (115-173)	296 (272-320)	288 (256-319)	413 (378-448)	419 (386-452)	439 (403-476)	446 (404-488)	476 (406-546)
	Female	140 (113-167)	279 (255-304)	302 (275-328)	345 (308-381)	305 (271-340)	355 (320-390)	349 (306-392)	382 (302-462)
AFR-E	Male	94 (82-105)	193 (181-205)	192 (178-206)	278 (266-290)	294 (279-309)	325 (309-341)	333 (306-361)	380 (316-443)
	Female	91 (78-103)	181 (170-192)	201 (194-209)	236 (229-243)	214 (205-223)	257 (245-268)	244 (229-259)	245 (225-266)
AMR-A	Male	278 (265-291)	247 (235-259)	257 (240-274)	305 (288-321)	338 (321-354)	369 (349-390)	387 (361-413)	364 (323-404)
	Female	262 (251-274)	236 (224-248)	234 (221-248)	261 (248-274)	307 (292-321)	335 (318-352)	346 (325-367)	348 (316-380)
AMR-B	Male	72 (42-103)	147 (104-189)	148 (124-171)	168 (143-194)	208 (148-268)	220 (160-280)	230 (171-290)	180 (120-239)
	Female	82 (51-112)	134 (78-191)	167 (153-182)	218 (111-324)	204 (153-255)	220 (168-271)	235 (183-286)	230 (178-281)
AMR-D	Male	193 (165-222)	352 (328-376)	299 (268-330)	408 (372-443)	392 (360-425)	387 (351-424)	353 (311-395)	306 (236-377)
	Female	192 (165-220)	339 (315-363)	316 (289-342)	332 (295-368)	287 (253-321)	328 (293-363)	287 (244-330)	241 (161-322)
EMR-B	Male	218 (189-247)	335 (311-359)	296 (265-327)	368 (333-404)	374 (341-407)	392 (355-428)	350 (308-392)	334 (264-404)
	Female	218 (190-245)	327 (303-351)	323 (297-350)	362 (325-398)	346 (311-380)	392 (357-427)	336 (293-378)	319 (238-399)
EMR-D	Male	174 (145-203)	342 (318-367)	312 (281-343)	388 (353-424)	409 (376-442)	446 (410-482)	442 (400-485)	420 (350-490)
	Female	174 (147-201)	333 (308-357)	348 (322-375)	352 (316-389)	319 (284-353)	385 (350-420)	372 (329-415)	409 (329-489)
EUR-A	Male	232 (204-260)	299 (274-324)	423 (401-445)	450 (433-468)	488 (467-508)	511 (487-535)	515 (473-556)	469 (407-530)
	Female	233 (211-255)	299 (279-318)	423 (406-439)	448 (435-461)	483 (469-497)	488 (467-509)	479 (451-507)	446 (411-481)
EUR-B	Male	263 (234-292)	374 (349-398)	396 (365-427)	352 (317-388)	396 (363-428)	366 (330-403)	358 (316-400)	300 (230-370)
	Female	238 (211-265)	372 (348-396)	344 (317-370)	333 (296-369)	383 (348-417)	352 (317-387)	358 (315-401)	303 (223-383)
EUR-C	Male	134 (122-146)	198 (185-210)	233 (218-247)	237 (225-249)	246 (231-261)	254 (237-270)	233 (206-260)	233 (169-297)
	Female	133 (121-146)	182 (171-193)	196 (188-204)	187 (180-194)	202 (193-211)	200 (189-211)	209 (194-224)	190 (170-211)
SEAR-B	Male	108 (96-120)	198 (185-210)	245 (231-259)	243 (232-255)	258 (243-273)	248 (231-264)	244 (217-272)	225 (161-288)
	Female	107 (94-120)	183 (172-195)	201 (194-209)	195 (188-202)	202 (193-211)	201 (190-212)	201 (187-216)	173 (153-194)
SEAR-D	Male	94 (82-106)	177 (165-190)	258 (244-272)	262 (250-274)	262 (247-277)	259 (243-275)	259 (232-286)	234 (170-298)
	Female	95 (82-108)	170 (159-182)	224 (217-232)	229 (222-236)	227 (218-236)	229 (218-240)	228 (213-243)	205 (185-226)

Numbers in brackets are the 95% confidence intervals

**Table 3-7 (continued)            Mean intake of fruits and vegetables by sub-region, age and sex (grams per person per day)**

Sub-region	Sex	Age Group (years)							
		0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
WPR-A	Male	264 (253-275)	345 (333-356)	366 (355-378)	376 (367-386)	450 (439-462)	491 (474-509)	446 (428-463)	415 (398-433)
	Female	232 (222-242)	342 (332-351)	352 (342-362)	383 (374-392)	486 (475-497)	485 (469-501)	440 (424-456)	386 (370-402)
WPR-B	Male	204 (187-221)	274 (266-282)	344 (336-352)	346 (338-354)	360 (350-370)	335 (320-350)	304 (285-323)	258 (221-294)
	Female	190 (170-209)	270 (261-279)	317 (308-325)	334 (326-341)	345 (336-355)	304 (292-317)	273 (257-288)	250 (221-278)

Numbers in brackets are the 95% confidence intervals

**Table 3-8 Standard deviations of fruits and vegetables by sub-region, age and sex (grams per person per day)**

Sub-region	Sex	Age group (years)							
		0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
AFR-D	Male	175.0 (156.7-198.2)	244.8 (228.7-263.3)	293.1 (272.6-316.9)	225.0 (202.4-253.3)	220.7 (199.6-246.8)	213.4 (190.4-242.8)	235.1 (208.6-269.3)	214.6 (174.1-279.9)
	Female	163.3 (146.0-185.3)	240.8 (224.8-259.3)	247.6 (230.2-267.9)	224.5 (201.2-253.9)	237.4 (215.3-264.6)	210.5 (188.4-238.5)	251.5 (224.4-286.1)	239.0 (192.8-314.6)
AFR-E	Male	96.2 (88.6-105.3)	178.6 (170.3-187.8)	254.9 (247.5-262.7)	220.7 (214.7-227.1)	231.5 (224.3-239.3)	192.6 (183.5-202.6)	176.3 (159.9-196.4)	165.8 (130.0-228.9)
	Female	105.5 (97.3-115.3)	155.9 (148.4-164.2)	163.4 (206.3-222.2)	157.6 (189.6-202.3)	171.6 (166.9-176.5)	168.2 (161.2-175.1)	153.5 (144.2-164.1)	115.4 (102.5-132.0)
AMR-A	Male	239.0 (230.2-248.4)	221.3 (213.0-230.3)	297.0 (285.3-309.8)	299.3 (288.0-311.5)	297.8 (286.5-310.0)	295.8 (282.0-310.9)	295.8 (278.5-315.5)	318.7 (292.5-350.1)
	Female	222.5 (214.4-231.2)	209.1 (201.1-217.8)	230.4 (221.2-240.5)	236.3 (227.3-246.0)	262.4 (252.4-273.2)	243.3 (231.6-256.2)	222.8 (209.1-238.4)	243.4 (222.8-268.1)
AMR-B	Male	153.3 (134.4-178.4)	294.3 (229.8-409.4)	470.1 (438.2-507.0)	260.0 (210.9-339.2)	390.3 (312.9-518.9)	390.3 (312.9-518.9)	390.3 (312.9-518.9)	390.3 (312.9-518.9)
	Female	160.2 (141.2-185.2)	341.8 (250.2-539.1)	293.6 (272.8-317.9)	718.2 (515.0-1185.6)	260.5 (190.7-410.8)	260.5 (190.7-410.8)	260.5 (190.7-410.8)	260.5 (190.7-410.8)
AMR-D	Male	175.0 (156.7-198.2)	244.8 (228.7-263.3)	293.1 (272.6-316.9)	225.0 (202.4-253.3)	220.7 (199.6-246.8)	213.4 (190.4-242.8)	235.1 (208.6-269.3)	214.6 (174.1-279.9)
	Female	163.3 (146.0-185.3)	240.8 (224.8-259.3)	247.6 (230.2-267.9)	224.5 (201.2-253.9)	237.4 (215.3-264.6)	210.5 (188.4-238.5)	251.5 (224.4-286.1)	239.0 (192.8-314.6)
EMR-B	Male	175.0 (156.7-198.2)	244.8 (228.7-263.3)	293.1 (272.6-316.9)	225.0 (202.4-253.3)	220.7 (199.6-246.8)	213.4 (190.4-242.8)	235.1 (208.6-269.3)	214.6 (174.1-279.9)
	Female	163.3 (146.0-185.3)	240.8 (224.8-259.3)	247.6 (230.2-267.9)	224.5 (201.2-253.9)	237.4 (215.3-264.6)	210.5 (188.4-238.5)	251.5 (224.4-286.1)	239.0 (192.8-314.6)
EMR-D	Male	175.0 (156.7-198.2)	244.8 (228.7-263.3)	293.1 (272.6-316.9)	225.0 (202.4-253.3)	220.7 (199.6-246.8)	213.4 (190.4-242.8)	235.1 (208.6-269.3)	214.6 (174.1-279.9)
	Female	163.3 (146.0-185.3)	240.8 (224.8-259.3)	247.6 (230.2-267.9)	224.5 (201.2-253.9)	237.4 (215.3-264.6)	210.5 (188.4-238.5)	251.5 (224.4-286.1)	239.0 (192.8-314.6)

Numbers in brackets are the 95% confidence intervals

**Table 3.8 (continued) Standard deviations of fruits and vegetables by sub-region, age and sex (grams per person per day)**

Sub-region	Sex	Age group (years)							
		0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
EUR-A	Male	347.9 (333.9-363.1)	284.7 (273.9-296.4)	350.3 (341.5-359.7)	312.2 (306.3-318.3)	345.4 (338.6-352.5)	283.7 (275.9-292.0)	344.6 (332.0-358.2)	289.7 (269.1-314.2)
	Female	280.4 (269.2-292.6)	226.2 (217.5-235.8)	290.2 (283.2-297.4)	254.2 (252.0-258.9)	262.4 (257.2-267.7)	265.8 (258.3-273.8)	317.1 (305.1-330.1)	266.6 (250.1-285.8)
EUR-B	Male	175.0 (156.7-198.2)	244.8 (228.7-263.3)	293.1 (272.6-316.9)	225.0 (202.4-253.3)	220.7 (199.6-246.8)	213.4 (190.4-242.8)	235.1 (208.6-269.3)	214.6 (174.1-279.9)
	Female	163.3 (146.0-185.3)	240.8 (224.8-259.3)	247.6 (230.2-267.9)	224.5 (201.2-253.9)	237.4 (215.3-264.6)	210.5 (188.4-238.5)	251.5 (224.4-286.1)	239.0 (192.8-314.6)
EUR-C	Male	96.2 (88.6-105.3)	178.6 (170.3-187.8)	254.9 (247.5-262.7)	220.7 (214.7-227.1)	231.5 (224.3-239.3)	192.6 (183.5-202.6)	176.3 (159.9-196.4)	165.8 (130.0-228.9)
	Female	105.5 (97.3-115.3)	155.9 (148.4-164.2)	163.4 (206.3-222.2)	157.6 (189.6-202.3)	171.6 (166.9-176.5)	168.2 (161.2-175.1)	153.5 (144.2-164.1)	115.4 (102.5-132.0)
SEAR-B	Male	96.2 (88.6-105.3)	178.6 (170.3-187.8)	254.9 (247.5-262.7)	220.7 (214.7-227.1)	231.5 (224.3-239.3)	192.6 (183.5-202.6)	176.3 (159.9-196.4)	165.8 (130.0-228.9)
	Female	105.5 (97.3-115.3)	155.9 (148.4-164.2)	163.4 (206.3-222.2)	157.6 (189.6-202.3)	171.6 (166.9-176.5)	168.2 (161.2-175.1)	153.5 (144.2-164.1)	115.4 (102.5-132.0)
SEAR-D	Male	96.2 (88.6-105.3)	178.6 (170.3-187.8)	254.9 (247.5-262.7)	220.7 (214.7-227.1)	231.5 (224.3-239.3)	192.6 (183.5-202.6)	176.3 (159.9-196.4)	165.8 (130.0-228.9)
	Female	105.5 (97.3-115.3)	155.9 (148.4-164.2)	163.4 (206.3-222.2)	157.6 (189.6-202.3)	171.6 (166.9-176.5)	168.2 (161.2-175.1)	153.5 (144.2-164.1)	115.4 (102.5-132.0)
WPR-A	Male	201.4 (190.9-213.2)	204.9 (198.7-206.7)	255.5 (249.4-261.9)	239.6 (234.2-245.3)	268.0 (261.4-275.1)	278.1 (268.1-288.8)	249.8 (237.8-263.1)	238.7 (220.0-260.9)
	Female	158.1 (149.8-167.4)	190.4 (184.6-196.7)	234.2 (228.7-240.1)	229.8 (224.8-235.1)	260.0 (253.7-266.6)	262.0 (252.9-271.7)	241.4 (231.6-252.1)	217.3 (203.7-232.8)
WPR-B	Male	110.1 (99.2-123.7)	136.1 (130.7-142.0)	161.5 (155.9-167.5)	157.3 (151.8-163.2)	167.7 (161.2-174.7)	167.1 (157.1-178.4)	141.3 (129.1-156.0)	147.1 (125.0-178.8)
	Female	107.5 (95.4-123.1)	146.0 (139.9-152.7)	150.2 (144.6-156.3)	153.2 (148.1-158.7)	161.9 (155.6-168.8)	148.4 (140.0-157.9)	130.9 (120.6-143.2)	136.2 (118.6-159.9)



### ***Quantitative and qualitative sources of uncertainty***

One major source of uncertainty is that the collective term “fruit and vegetables” comprises a very heterogeneous group of foods in different countries and cultures. For example, in a western diet, fruit and vegetables include roots, leaves, stems, fruit, and seeds from more than 40 botanical families <sup>191</sup>. They can be consumed fresh or cooked in many different ways that will influence their biochemical content. Biochemical composition also varies among different types of the same fruit. For example, the vitamin C content of different types of apple varies 10 fold. Composition is also subject to differences in growing conditions, such as soil composition, and storage conditions, a factor of increasing importance as commodities are transported globally to ensure year-round supply in developed countries. It was decided to keep fruit and vegetables as a single entity for two main reasons. First, there remains uncertainty as to which components of fruit and vegetables would confer a protective effect. Even if the relevant constituents had been correctly identified, the nature of their relationship to disease risk would still need to be specified correctly. Second, obtaining intake data for specific foods (for this project) would have been even more difficult than for fruit and vegetables taken together.

Seasons also influence the amounts and variety of fruit and vegetables consumed. Furthermore, evidence is emerging to link seasonality of consumption of fresh fruit and vegetables to the pattern of cardiovascular disease mortality in some countries <sup>5</sup>. It is possible that the consequences for disease of an annual cycle of seasonal excesses and out-of-season shortages (as in the less economically developed countries of the former Soviet Union) may be quite different to the effects of consuming a similar annual level where counter-seasonal supplies ensure that there is no period of very low consumption (as in the affluent countries of north-west Europe). However, in the absence of either information on national variations in fruit and vegetable intake or of relevant epidemiological evidence, it was assumed that it is the long-term annualized average of fruit and vegetable intake that best predicts disease risk. Yet the need for caution is illustrated by the case of alcohol, where risk of cardiovascular disease appears to be more sensitive to the pattern of alcohol consumption over time as well as the total amount consumed <sup>192</sup>. It is also assumed that the estimates used represent annualized mean intakes.

The choice of data sources may also have influenced the final estimates. It was decided that dietary surveys of representative population samples would be used as the gold standard in this project. However, the quality and validity of individual level data depend on the ability (and willingness) of each individual to provide accurate information on his/her dietary intake<sup>150</sup>. If the aim is to assess current diet, the procedures involved in measuring dietary intake may lead to changes in behaviour. If the aim is to measure past diet, then the reliability of the information provided will depend on memory and on the conceptual abilities of the respondents. Other difficulties include the conversion of food frequencies into mean intakes in surveys that used food-frequency questionnaires, and the limitations and completeness of the various computerized food analysis softwares used in different countries. Finally, it is possible that the survey respondents were not entirely representative of the reference populations, even though most data were from national surveys of dietary intakes.

In dietary surveys, variation, as measured by standard deviations, is influenced by the method used to collect data. As noted earlier, it is recognized that methods based on only one day of data collection (e.g. one 24-hour recall or one day of food record) tend artificially to increase standard deviations due to large intra-individual variation in intakes<sup>193</sup>. Most of the surveys used in this study were based on only one day (sometimes two days) of information. It is thus expected that standard deviations were overestimated. However, as described earlier, the method used to pool data from two or more surveys tends to underestimate the level of uncertainty surrounding the pooled standard deviation for the sub-region based on a sub-sample of countries if there is substantial between-country variation.

Although I sought to obtain dietary survey data for each country, few such data exist and thus food availability statistics were used for sub-regions where no or few data were available. The validity of food balance sheet statistics depends on the availability and validity of the basic national data on which they are based, including statistics on population, production, stock, import and export. These are known to vary among countries, and from one year to another, both in terms of coverage and accuracy<sup>194</sup>. The net availability of vegetables is affected by factors such as non-commercial production and uncertain losses to animal feed, spoilage and waste. However, the FAO performs external consistency checking using supplementary information such as household survey results as well as the application of relevant technical, nutritional and

economic expertise in an attempt to eliminate these potential deficiencies. In this study I have used at least three years of FAO data in order to try to reduce the effect of potential yearly variations in coverage and accuracy. However, the current lack of information on adjustment factors to apply to FAO Food Balance Sheet data in developing countries creates a source of uncertainty. Finally, extrapolation from one country to others remains an important source of uncertainty, especially in the presence of inter-country heterogeneity.

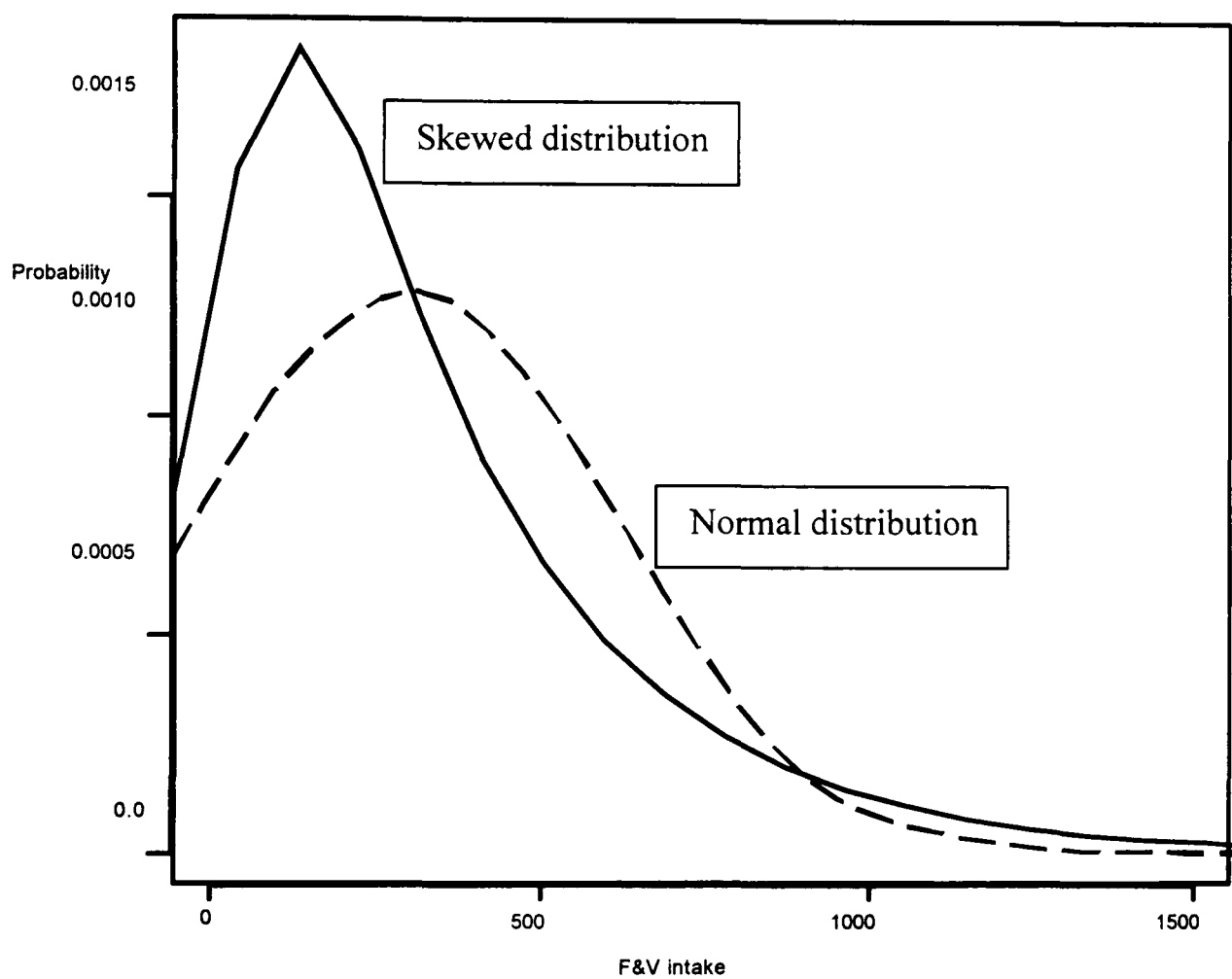
### ***Sensitivity analysis: skewed distributions and calculation of the attributable fraction***

Data from the United States were used to evaluate the possible effects of skewness in the distribution of fruit and vegetable intake on the calculation of the attributable fraction for AMR-A region. The data indicated a positive skewness ranging from 1.5 to 3. To approximate this type of skewed distribution, the Weibull PDF was utilized by varying the shape and scale parameters (decreasing the shape parameter of a Weibull increases positive skewness away from a normal distribution).

Figure 3-2 illustrates a normal distribution with a fruit and vegetable mean intake of 300 g/day and standard deviation of 300 g/day. A significant part of the population with a normal distribution is truncated at zero consumption (approx 10% of the population in this example). The skewed distribution is the approximation of what the actual intake data resembles (skewness is 2 in this illustration). Note that all data in the skewed distribution are non-zero (even though it appears that there are zero values).

The attributable fraction was then calculated, for the two different distributions, for ischaemic heart disease. The result for the truncated normal distribution with probability mass at zero was 35%. Incorporating a skewness value of 2 resulted in an attributable fraction of 38%, thus suggesting that the general approach taken is the more conservative.

**Figure 3-2** Illustration of skewed and normal distribution based on data from the United States.



**Conclusions**

This chapter presents the methods used for estimating the consumption of fruit and vegetables worldwide. Although there are several different sources of dietary data available at a national level, an innovative approach was developed for estimating fruit and vegetable intake to fulfil the requirements for the global burden of disease study. The approach had to take into account the large variations in data sources available for many countries. Available data estimations and extrapolations provided mean (and standard deviations) for fruit and vegetable intake by sub-regions of the world. The

fruit and vegetable intake estimations are presented by sub-region, gender and age groups. The results show that the availability and quality of fruit and vegetable intake data varies considerably between countries, and especially between world sub-regions. Unsurprisingly, the most comprehensive data from nationally representative intake surveys was found from Europe and the USA. Africa had the greatest paucity of data.

There are a large number of potential sources of uncertainty in the methods used for intake estimation. These include parameter uncertainty, which can sometimes be quantified (e.g. due to measurement error), and model uncertainty due to gaps in theory, measurement technology or simply lack of data, plus the extrapolation of exposure from one population to another. The last issue was a problem for estimating regional fruit and vegetable intake as in some regions of the world there are few studies reporting individual dietary intake. However, it is felt that the methodology for estimating intake is justified in the context of the Global Burden of Disease study. Given the limitations of the data, there were two options for this global project; either exclude those regions without good quality representative intake survey data (meaning that the focus of diet as a risk factor would have been in developed countries, ignoring the rapid epidemiological and nutrition transition occurring worldwide); or use clear assumptions and extrapolations, which may stimulate the need for more research on dietary intake in developing and transition countries with poor resources.

The following chapters present the relevant risk factor epidemiology, discussing how the relationship between fruit and vegetable intake and major non-communicable diseases is quantified for the global burden of disease analysis.

## **Chapter 4 Risk factor epidemiology**

This chapter explores the putative relationship between fruit and vegetable consumption and the outcomes being studied in this thesis, focussing on the question of whether such relationships can be considered causal.

The choice of outcomes attributable to low fruit and vegetable consumption was guided mainly by previous reviews of the literature. Those of Ness and Powles<sup>33</sup> and Law and Morris<sup>38</sup> suggested a protective effect of fruit and vegetables for coronary heart disease and stroke. The review from the World Cancer Research Fund (WCRF) and American Institute of Cancer (AIC) looking at a wide range of cancers<sup>13</sup> concluded that the evidence for fruit and vegetables decreasing cancer risk was convincing for lung and digestive tract cancers. In this thesis, cancers of the lung, oesophagus, stomach, colon and rectum were examined, leaving cancers of the mouth and pharynx for future research. Cancers for which the WCRF/AIC review reported only a probable association (larynx, pancreas and bladder cancers) or limited evidence of an association (cancers which may have a hormonal aetiology including ovary, endometrium, thyroid and prostate) were not included in the CRA project at this stage.

Although there is also limited evidence for other health outcomes such as diabetes, chronic obstructive pulmonary disease and cataract<sup>36,37</sup>, it was decided not to include these in the 2000 revision of the GBD project because the number of published studies is currently too limited to draw conclusions on the size of any effect on these outcomes. Again, consideration of the relevant evidence is a subject for future research. Although other types of cardiovascular disease, such as peripheral vascular disease, share most risk factors with ischaemic heart disease and occlusive stroke, these outcomes were also excluded from the current thesis because of the so far limited information on a possible relationship with fruit and vegetable intake.

### ***Evidence for causal relationships with the selected health outcomes***

In considering the implications of research for exposures and outcomes in epidemiological studies, it is essential to distinguish mere association from causality. Bradford Hill's criteria of biological plausibility, temporality, strength, consistency, dose-response, and experimental evidence, were considered in order to determine the

likelihood of causality for the association of fruit and vegetable intake with the six selected health outcomes.

### **Biological plausibility**

Evidence of causality for the relationship between fruit and vegetable consumption and health can be obtained from the identification of possible biological mechanisms. A number of mechanisms have been proposed <sup>191</sup>. They generally involve specific nutrient and non-nutrient constituents of fruit and vegetables, including antioxidants and various other micronutrients in fruit and vegetables. However, few attempts have been made simultaneously to explore a combination of potential mechanisms.

The issue of biological plausibility is extremely complex and evidence remains fragmentary. There are several reasons for this. First, it is very difficult, in conventional epidemiological studies, to specify precisely the exposure to different types of foods or food components over a prolonged period of time. As demonstrated in chapter 3, obtaining valid information on individual dietary intake is very difficult. Even where this is possible, it is likely that the true content of the reported foods will have varied due to differences within particular types of food (such as different brands of oranges), differences in methods of food preparation, and seasonal variation in food composition. Second, while the growth in understanding of molecular mechanisms of disease is identifying many new factors, in particular non-nutrient components of food which may be important in preventing specific diseases, in many cases their existence, let alone their possible importance, was not known at the time when cohort studies now reporting results were established (e.g. glucaninolates in brassicas<sup>195</sup> and isoflavones in soya<sup>196</sup>, both of which appear to reduce incidence of some types of cancer). The incompleteness of current food composition tables is a major limitation for the assessment of the possible effect of varying intakes of these substances.

Consequently, much of the available research on the assessment of biological mechanisms is based on studies in animals and often involves the administration of pharmacological, rather than physiological, doses of various substances. This raises important questions about the applicability of such studies to humans. These reservations must therefore be borne in mind when interpreting the evidence discussed below.

## Cancer

The immediate cause of cancer is damage to DNA at some stage during the cell cycle<sup>197</sup>. At the risk of over-simplification, this can arise from one of three broad mechanisms.

One is genetic, with obvious examples being certain childhood cancers, certain forms of breast cancer (with the same genetic abnormality possibly also causing some forms of prostate cancer)<sup>198</sup>, as well as disorders causing abnormalities that have a high probability of malignant transformation, such as familial polyposis coli.

A second group of cancers are linked with endogenous hormonal patterns. The association between reproductive history and some forms of breast cancer is perhaps the best-known example<sup>199</sup>. There is, however, growing evidence that the incidence of some of these cancers is determined, to some extent, by patterns of growth in early life<sup>200</sup>, mediated by levels of insulin-related growth factor. Hormonal influences are also likely to be important in the aetiology of prostate cancer and some cancers linked with obesity.

A third mechanism involves the action of exogenous carcinogens such as those compounds produced from combustion of tobacco. They include a wide range of other chemical agents, such as asbestos or benzene, ionising radiation, and, as is being increasingly recognized, many infectious agents (e.g. *Helicobacter Pylori* as a major cause of stomach cancer).

These factors may, of course, act together in certain cases. Thus, the risk of colorectal cancer appears to be influenced by diet, and by implication, exogenous carcinogens. It is also influenced by an individual's acetylator status, which is determined genetically and which leads to certain dietary derived carcinogenic chemicals being excreted either in the bile, when they can then act on colonic mucosa, or in the urine<sup>201</sup>. A greater risk is also associated with high circulating levels of the growth promoting hormone IGF-1<sup>202</sup>

From this brief review it is apparent that fruit or vegetable consumption might only be expected to influence directly the risk of certain cancers and not others, and even where they do have a role this is likely to be modulated by a wide variety of other factors, the importance of which will vary in different populations.



The substances present in fruit and vegetables that might have an impact on cancer incidence can be divided into agents that block the action of carcinogens (Table 4-1), agents that suppress the progress of carcinogenesis (Table 4-2), and antioxidants, which can prevent oxidative DNA damage. Some of these agents have both complementary and overlapping mechanisms of action.

**Table 4-1      Selected blocking agents present in fruit and vegetables**

Component	Fruit/ vegetable
Terpenes <sup>203</sup>	Citrus fruit
Organosulphides <sup>204</sup>	Allium vegetables: onion, leek, garlic, scallions, chives
Indoles <sup>205</sup>	Cruciferous vegetables
Flavonoids <sup>206</sup>	Onions, apples, citrus fruit, tea, coffee, cola, alcoholic beverages
Carotenoids <sup>207</sup>	Yellow and orange vegetables and fruits, green leafy vegetables

**Table 4-2      Selected carcinogenesis suppressing agents present in fruit and vegetables**

Component	Fruit/ vegetable
Protease inhibitors <sup>208</sup>	Legumes, potatoes, spinach, broccoli, cucumbers
Terpenes	Citrus fruit
Isothiocyanates	Cruciferous vegetables
Plant sterols <sup>209</sup>	Vegetables, beans, seeds
Carotenoids	Yellow and orange vegetables and fruits, green leafy vegetables

Antioxidants include certain vitamins, such as vitamins C <sup>210</sup> and E <sup>211</sup>, carotenoids <sup>212</sup> (including beta-carotene and other compounds such as flavonoids), and selenium. These act by scavenging free radicals that would otherwise damage DNA. In doing so they would reduce the impact of certain exogenous carcinogens.

In general, any protective effect that fruit and vegetables might exert is more likely to be apparent with cancers where exogenous carcinogens play a major part. Examples

include lung, stomach, and colorectal cancer. Evidence from observational studies seems to support this. The WCRF/AIC review of the literature<sup>13</sup> concluded that the evidence for fruit and vegetables decreasing cancer risk was convincing for oral-pharyngeal, lung and digestive tract cancers; that there was a probable association for larynx, pancreas and bladder cancers; and that the evidence was limited for cancers which may have a hormonal aetiology including those of the ovary, endometrium, thyroid, and prostate.

The case of stomach cancer is perhaps best understood<sup>6</sup>, showing the complexity involved. *Helicobacter Pylori* infection is thought to lead to cancer by causing inflammation in the pylorus. This would lead to the production by the host of interleukin 1 $\beta$ , a cytokine with a wide range of effects. These include both the generation of an intense local inflammatory response and a powerful inhibition of acid secretion. In susceptible individuals, the combined effects would lead to progressive atrophy, metaplasia and eventually carcinogenesis. There is, however, a considerable degree of individual variation in the probability that *Helicobacter Pylori* infection will follow this course. One factor is the existence of polymorphisms in the interleukin 1 $\beta$  gene that modulate the inflammatory response. A second is modulation of the progression to atrophy by dietary antioxidants. Thus, an individual with *Helicobacter* infection may be protected by genetic status, diet, or both. The latter is complicated further by the presence of polymorphisms in genes controlling other factors in the cytokine cascade, such as the Tumour Necrosis Factor. Research so far has been based largely on laboratory work in animals. Epidemiological research must take account of the long time scale involved but must also find ways of categorising individuals' dietary exposures and genetic status.

Most research has been at a more general level, examining either the effect of a specific compound or of overall fruit and vegetable consumption. Research into the former has yielded mixed results. While many studies have shown an association between high beta-carotene intake and reduced risk of cancer, especially lung and stomach cancer<sup>213</sup>, a highly publicized study among smokers receiving vitamin supplements, including beta-carotene, found that they were associated with an increased rate of lung cancer. Similarly, while a recent meta-analysis found a small reduction in the risk of breast cancer with high levels of fruit and vegetable consumption<sup>214</sup>, some large studies looking at vitamin supplements have found no effect<sup>215 216</sup>. However, the effect of

dietary composition in the post-pubertal years is likely to be greatest for such cancers with hormonal aetiologies, as diet during this phase of growth may influence breast cancer risk substantially via its effect on body size, age of menarche, etc.

Given the many substances potentially involved in protecting against cancer, and the diverse mechanisms involved, these mixed results have highlighted the need to look at non-nutrient components of fruit and vegetables. Research is now investigating, among others, the potential impact of other food components such as bioactive compounds (allium compounds, dithiolthiones, isothiocyanates, terpenoids, isoflavones, protease inhibitors, phytic acid, polyphenols, glucosinolates and indoles, flavonoids, plant sterols, saponins, and coumarins). For example, a controlled trial of the consumption of 300 g Brussels sprouts per day for 3 weeks reported a significant decrease of 28% in oxidative DNA damage<sup>217</sup>.

In summary, there are many possible mechanisms by which fruit and vegetable consumption might reduce the risk of cancer but our knowledge is handicapped by the uncertainty with regard to the many pathways involved in carcinogenesis and the relative quantitative importance of each of the mechanisms that, on current knowledge, could plausibly be involved. However, it appears that the impact of diet is likely to be greatest for cancers caused by specific external carcinogens, such as gastrointestinal and lung cancer, and less important for cancers where endocrine factors play a greater role, such as breast and prostate cancer. The overall importance of diet in a given population will clearly reflect the prevalent pattern of exposure to specific carcinogens as well as differences in genetic susceptibility. Thus, an agent that acts to protect against the effects of a particular carcinogen will have less of an effect in a population where exposure to that carcinogen is rare than where it is common.

### **Cardiovascular disease**

As with cancer, the multiple mechanisms by which fruit and vegetable consumption might act on the risk of cardiovascular disease are difficult to disentangle because of inadequate understanding of the determinants of disease. Most research has concentrated on atherosclerosis, but other potential mechanisms by which fruit and vegetables could impact indirectly on cardiovascular risk include a link with blood pressure modulation, through the high potassium content of some fruit and vegetables<sup>191, 218</sup>, or with chronic respiratory disease (associated with fruit and vegetables—and their constituents) and vascular disease risk. For the sake of simplicity this short review

will focus on ischaemic heart disease, although some issues are also relevant to cerebrovascular disease.

Atheroma is thought to arise as a result of monocytes adhering to endothelial cells and migrating into the arterial intima where they become macrophages, taking up low-density lipoprotein, subsequently becoming foam cells. The role of fruit and vegetables in monocyte adhesion is increasingly well understood. Methionine, derived from dietary protein, is converted within cells to homocysteine. In this process, a methyl group that is essential for DNA synthesis and certain other compounds are generated. The homocysteine is then either remethylated, in a reaction in which folic acid and vitamin B12 are essential co-factors, or is irreversibly broken down to cysteine, in a reaction that requires vitamin B6 as a co-factor<sup>219</sup>. Thus, a deficiency of any of these vitamins will give rise to an elevated level of homocysteine. However, the remethylation reaction may also be compromised by a mutation (677C→T) in the enzyme involved. This mutation is present in about 15% of the European population<sup>220</sup>. High levels of homocysteine contribute to the generation of free radicals, and thus oxidative damage, in endothelial cells. This leads to deactivation of cellular nitric oxide<sup>221</sup> and thus the aggregation of monocytes and platelets, as well as vasoconstriction. These, in turn, promote atherogenesis. There is now compelling epidemiological evidence to link homocysteine and vascular disease. A meta-analysis showed that the risk of cardiovascular disease increased with plasma homocysteine, with odds ratios of 1.6 (1.4-2.3) and 1.8 (1.4-2.3) per 5 µmol/L increment in plasma homocysteine in men and women respectively. The relationship was similar for cerebrovascular disease<sup>222</sup>. It is important to note, however, that it appears that naturally occurring folate would be only about half as effective in reducing plasma homocysteine as pharmacologically produced folic acid, and emerging research suggests that the homocysteine mechanism is not as important as previously thought.

It is also possible that dietary factors might be involved in the mechanisms by which the monocytes, turned into macrophages, become laden with low-density lipoprotein. This involves the expression of two scavenger receptors on the macrophage surface<sup>223</sup>, a phenomenon that is modulated by a transcription factor<sup>224</sup>, the activity of which can be affected by certain compounds such as glitazones. Further research is required to determine whether food components play a similar role.

It has been suggested that other components of fruit and vegetables, in particular antioxidants, act at other stages in the process of atherogenesis. This theory gains credence from the observation that differences in antioxidant activity are strongly associated with differences in cardiovascular disease between the Baltic States and Scandinavia <sup>225</sup>. Such compounds could act by reducing the oxidation of low-density lipoprotein, thus reducing the formation of fatty streaks and plaques. These antioxidant compounds include vitamin C, which is involved in free radical scavenging, haemostasis and in the stabilisation of lipid membranes <sup>226</sup>, and beta-carotene, which neutralizes singlet oxygen molecules and prevents chain formation, so reducing oxidative processes that are important in atherogenesis <sup>227</sup>. Flavonoids also inhibit the oxidation of low-density lipoprotein and reduce thrombotic tendencies. They are believed to act by the scavenging of superoxide anions, singlet oxygen and lipid peroxy radicals. Flavonoids also inhibit cyclo-oxygenase, so reducing platelet aggregation and thus the risk of thrombosis.

Observational studies support a strong inverse association between plasma levels of vitamins C and E and cardiovascular mortality <sup>228-231, 232</sup>. However, only a few studies have reported a significant inverse relationship between vitamin C specifically and cardiovascular risk <sup>233</sup>. Several reviews have found no significant benefit from vitamin C after controlling for other antioxidant intake or multivitamin use <sup>234 235</sup>. Even those that reported a benefit from vitamin C differ with regard to the point at which an effect appears and the potential magnitude of the relationship. Some studies indicated an increased risk of cardiovascular disease only at very low levels of plasma vitamin C, with no effect within the range seen in most populations. Other studies have reported a significantly reduced risk only in persons with the highest levels or with supplemental intake. However, a recent study showed a significant decrease in cardiovascular and ischaemic heart disease risk throughout the normal plasma range <sup>233</sup>. Similarly, although results from many observational studies suggest that higher serum levels of beta-carotene reduce the risk of cardiovascular disease, systematic reviews have concluded that evidence for a protective effect is inconsistent <sup>235 236</sup>.

As with studies of cancer, there is no clear evidence from intervention trials that antioxidant supplements reduce the risk of cardiovascular disease <sup>237 238 239 240</sup>. In the case of beta-carotene there is even some evidence of harm. Several trials were not, however, designed specifically to assess cardiovascular disease risk and did not provide

data on non-fatal cardiovascular endpoints. In addition, most trials may have been of insufficient duration<sup>241</sup>. Some authors have suggested that the apparent protective association found in observational studies could be due to residual confounding by differences in socioeconomic status, health behaviour, and dietary intake<sup>242</sup>.

Many of the same challenges that arise with studies of the aetiology of cancer also apply to ischaemic heart disease. First, if fruit and vegetables do affect atherogenesis, then their effect will be modulated by other important factors that are involved in atherogenesis and that are also influenced by diet. This is particularly the case for high-density and low-density lipoproteins. These are determined primarily by the amount and nature of fat in the diet but are also influenced by alcohol consumption, with the precise effect determined by the pattern of drinking. In addition, it is important to remember that atherogenesis is only one factor involved in myocardial infarction. Another is thrombosis, which may also be influenced by certain dietary factors<sup>243</sup>.

Second, and less well recognized, cardiovascular disease embraces a wide variety of different processes. In particular, it is becoming clear that some myocardial infarctions in young people have a different aetiology. For example, binge drinking of alcohol is recognized as an important factor in the high death rate from cardiovascular disease in the former Soviet Union<sup>31</sup>, and it has been estimated that a quarter of non-fatal myocardial infarctions in Americans aged between 18 and 45 are attributable to cocaine<sup>244</sup>. Even within the more conventional understanding of ischaemic heart disease there are clearly differences between those whose atheroma predominantly takes the form of plaques that are lipid-rich, and thus likely to lead to plaque rupture and so to acute infarction, and those that are predominantly fibrous, with smooth muscle proliferation, which are more likely to cause progressive angina<sup>245</sup>.

## **Experimental evidence**

### **Trials of dietary changes**

There is little experimental evidence for the health effects of increasing fruit and vegetables in the diet. Obviously foods that are part of a usual diet are not easily amenable to traditional trials in the general population. Although no trial examined just giving advice to eat more fruit and vegetables on the disease outcomes considered in this thesis, a few trials of dietary advice in secondary prevention of coronary heart disease have included advice to eat more fruit and vegetables<sup>246-248</sup>.

The Diet and Reinfarction Trial (DART) was set up to examine the role of diet in secondary prevention of myocardial infarction. Participants were randomized to receive advice or no advice on each of three dietary factors: a reduction of fat intake and an increase in the ratio of polyunsaturated to saturated fat, an increase in fatty fish intake, or an increase in cereal fibre intake. Although the fat advice arm of the trial was associated with an increased fruit and vegetable consumption of about 50 g/d, no effect on total mortality at 2 years was observed (relative risk = 1.00, 95% CI 0.77–1.30) and there was no effect on ischaemic heart disease events (ischaemic heart disease deaths plus non-fatal myocardial infarction: relative risk = 0.91, 95% CI 0.71–1.16)<sup>249</sup>. It is possible, however, that the increase in fruit and vegetable consumption was too small, or that 2 years was not long enough, to produce a detectable effect. However, on the latter issue evidence from an ecological study in Poland suggests that population dietary changes can lead to reductions in ischaemic heart disease deaths in similar timescales<sup>28</sup>

The Lyon Diet Heart Study investigated whether a Mediterranean-type diet could reduce the rate of recurrence after a first myocardial infarction compared with a prudent Western-type diet. Intermediate analysis showed a marked protective effect after 27 months of follow-up (73% reduction in rate of recurrence and death from cardiovascular causes, relative risk = 0.27, 95% CI 0.11–0.65) which was maintained for four years after infarction (relative risk = 0.28, 95% CI 0.15–0.53)<sup>250</sup>. The increase in fruit and vegetable consumption in the intervention group was thought to be an important factor in risk reduction. However, as in the DART study, diet changed in a number of ways during the trial and it is thus impossible to estimate the specific influence of increased fruit and vegetable intake in either trial.

Evidence that increasing fruit and vegetable intake alone may be important as a dietary intervention in reducing cardiovascular disease risk comes from the Indian Experiment of Infarct Survival (IEIS)<sup>247</sup>. This randomized controlled trial showed that the consumption of a low-fat diet enriched with fruit and vegetables compared with a standard low-fat diet was associated with about 40% (relative risk = 0.60, 95% CI 0.31–0.75) reduction in cardiac events and 45% (relative risk = 0.55, 95% CI 0.34–0.75) reduction in mortality in 406 men with acute myocardial infarction after one year. These findings suggest a very rapid effect of dietary change on incidence of and

mortality from ischaemic heart disease that would appear to be difficult to explain otherwise.

Some recent trials also assessed the impact of increased fruit and vegetable intake on blood pressure. In the Dietary Approaches to Stop Hypertension (DASH) trial, hypertensive participants were fed a control diet for three weeks and then were randomized to receive for eight weeks either the control diet, a diet rich in fruit and vegetables, or a combination diet rich in fruit and vegetables, and reduced in saturated fat, fat and cholesterol <sup>251 252</sup>. Both the combination diet and the fruit-and-vegetables diet significantly reduced systolic and diastolic blood pressure. After eight weeks, 70% of the participants on the combination diet had a normal blood pressure, 45% of those on the fruit and vegetable diet, and 23% of those on the control diet. Unsurprisingly the fruit and vegetable diet produced few changes in blood lipids and had less effect on blood pressure reduction than the combination diet. Both diets showed that they could potentially help reduce coronary heart disease risk. However, studies with a longer follow-up would be required to assess the true long-term effect of such changes.

Another trial assessed the specific effect of increased guava intake in hypertensive individuals <sup>253</sup>. After four weeks, the diet rich in guava (0.5–1 kg/day) was associated with 7.5/8.5 mmHg net decrease in mean systolic and diastolic pressures compared with the control group, a significant decrease in serum total cholesterol (7.9%), triglycerides (7.0%), and an insignificant increase in HDL-cholesterol (4.6%) with a mild increase in the ratio of total to HDL-cholesterol. The authors suggested that an increased consumption of guava fruit could cause a substantial reduction in blood pressure and blood lipids without a decrease in HDL-cholesterol. These changes were attributed to its high potassium and soluble fibre content, respectively. Further research is needed to confirm this hypothesis with more widely applicable dietary changes.

### **Nutrient supplement trials**

Due to the lack of trials of increased fruit and vegetable intake on health outcomes, most data from intervention studies relate to studies of nutrient supplements. Unfortunately, these trials have generally been of small sample size and relatively short duration <sup>191</sup>.

In contrast to the results of observational studies, findings from trials of antioxidant and vitamin supplementation have mostly shown no effect on mortality, cardiovascular



events or incidence of cancer <sup>254 255 256 257</sup>. There has even been some concern following two trials that showed an increased risk of lung cancer mortality with beta-carotene and vitamin A supplements in the Alpha-Tocopherol, Beta-Carotene and Cancer Prevention (ATBC) study <sup>258</sup> and the Beta-Carotene and Retinol Efficacy Trial (CARET) <sup>259 259</sup>. However, the recent Heart Protection Study (HPS) showed neither benefit nor harm of supplementation with antioxidant vitamins after 5.5 years follow-up. This double-blind randomized trial with a 2x2 factorial design investigated, in over 20 500 persons, the use of simvastatin and antioxidant vitamins (vitamin E, vitamin C, and beta-carotene) <sup>260</sup>. It did not, however, assess the effect of folate, a micronutrient that, at least on the basis of in vitro studies, might have been expected to have an effect<sup>261</sup>.

One exception is the Linxian trial in China <sup>262</sup>. This trial showed reduced total mortality after 6 years in the group supplemented with beta-carotene, alpha-tocopherol and selenium compared with the placebo group. However, it is not possible to identify which micronutrient contributed most to the lower mortality. Some trials have also suggested that vitamin E supplementation may prevent ischaemic stroke in high-risk hypertensive patients <sup>263</sup>.

These generally negative findings, whilst initially surprising, are not entirely unexpected given the large number of potentially active compounds in food and the scope for interactions, both with other exogenous substances and genetic status. Given that there are very few randomized-controlled trials that investigated the association of fruit and vegetable consumption with disease outcomes, current evidence of causality is mainly based on that derived from observational studies.

## **Strength of association**

The review of the evidence from cohort and case-control studies generally supports the hypothesis that a high dietary intake of fruit and vegetables is protective for cardiovascular disease and certain cancers (see later). However, although many studies have shown a significant inverse relationship between fruit and vegetables and cancer or cardiovascular disease, the potential size of the protective effect has varied among studies. Some have shown an increased risk of disease at very low intakes <sup>264</sup>, while others have shown a reduced risk only in individuals with high intakes. Those studies that reported statistically significant associations between the level of fruit and vegetable consumption and disease outcome have, in general, produced consistent

estimates of relative risks comparing high versus low intake. This is a relatively strong association for the outcomes discussed in this chapter, especially taking into account the dilution inherent in dietary exposure measurement.

Some authors have suggested that the association could be explained by confounding<sup>265</sup>. The studies and reviews included in this document have considered the effect of confounders, but not all studies may have adequately adjusted for them. Although confounding cannot be completely excluded as a partial explanation for the observed association, recent large prospective nutrition studies provide evidence for a protective association of fruit and vegetables after adjusting for a wide range of potential risk factors (see chapter 5).

## **Consistency**

Most studies of fruit and vegetable consumption show a generally consistent inverse relationship with the six disease outcomes in different populations (see chapter 5). There were virtually no studies of whole foods (thus excluding nutritional supplements) that showed harmful associations, and many of the studies that reported a negative association exhibited an insignificant inverse trend. The major caveat to this statement is that there have been few studies in populations from developing countries.

## **Temporality**

It is virtually axiomatic that fruit and vegetable consumption will precede disease outcomes. The many cohort studies reviewed here that have long follow-up periods provide more convincing evidence for temporality, as they are less likely to have been affected by information bias, a major source of bias in case-control studies (e.g. recall bias).

Evidence from the epidemiological literature shows that, in general, those people in the highest categories of fruit and vegetable consumption have lower risk of cardiovascular disease and cancers compared with those in the lowest consumption categories. Many of the studies also reported a significant trend between the quartiles, quintiles or tertiles of consumption and disease risk, and a few studies have reported significant effects with fruit and vegetable treated as a continuous variable (see chapter 5).

The WCRF/AIC review<sup>13</sup> attempted to estimate the dose-response relationship between fruit and vegetable intake and various cancers. Using the strength of association across all the large studies in the review, the authors adjusted the odds ratios and relative risk

estimates to a common baseline before fitting a regression line through the resulting points. There was a need to shift curves so that all studies had a common baseline as there is no “zero consumption group” found with other risk factors such as smoking and alcohol consumption. When looking at the relationship between lung cancer and vegetable intake, the fitted regression line showed that the relative risk decreases by about 50% as intake increases from 150 g/day to 400 g/day. An intake of >400 g/day was always associated with a lower risk than an intake of 100 g/day or less. For the association of stomach cancer with fruit intake, the fitted regression line showed that the relative risk decreased by about 50% as intake increased from 50 g/day to 300 g/day. An intake of >150 g/day was always associated with a lower risk than an intake of 100 g/day or less.

## **Conclusions**

There are still many uncertainties with regard to the mechanisms that lead to common diseases, in the roles that fruit and vegetables could play in these mechanisms, and in the particular substances in fruit and vegetables that are especially important. Different studies have suggested that flavonoids, carotenoids, vitamin C, folic acid, and fibre (amongst others) could play a protective role. However, it must be kept in mind that studies based on single food constituents may underestimate the effects of exposures to foods that are chemically complex, especially where different constituents act at various stages along metabolic pathways. Also, single constituents can be a marker for other active constituents (as the conflicting results between observational studies and trials have suggested for beta-carotene)<sup>255</sup>, or even for a combination of constituents that are responsible for the protective effect. Until these mechanisms are better understood, it will not be possible to determine with any certainty, what precise role specific components of fruit and vegetables might play. What can be said with some confidence is that there is a wide variety of substances within fruit and vegetables that appear to play a role in disease prevention.

The health outcomes selected for the GBD study were ischaemic heart disease, cerebrovascular disease, and cancers of the lung, stomach, oesophagus, colon and rectum. The choice of outcomes was guided by previous reviews of the literature which reported a consistent protective effect of fruit and vegetable intake on these health problems (see previous section)<sup>32 33, 13</sup>. Before finally including these outcomes in the GBD study, Bradford Hill’s criteria of biological plausibility, temporality, strength,

consistency, dose–response, and experimental evidence, were considered in order to determine the likelihood of causality for the association of fruit and vegetable intake with these six selected health outcomes. There is growing evidence for an association with other outcomes, including cancers of the bladder, pharynx and larynx <sup>13</sup> and obesity and diabetes <sup>266</sup>, but it was considered that there were an insufficient number of epidemiological studies for inclusion in this study.

The subsequent chapters describe the methods and results from the systematic review and the meta-analyses used to quantify the relationships between fruit and vegetable intake and these six disease outcomes.

## **Chapter 5 Systematic review & meta-analysis methods**

The associations between fruit and vegetable intake and various disease outcomes in the thesis are based on a systematic review of the literature. This provided evidence about the direction and size of the relationship between fruit and vegetable consumption and the selected disease outcomes. This was complemented with meta-analyses for four disease outcomes. This chapter describes the methods used to conduct the systematic reviews and meta-analyses. The results, quantifying the risk factor-disease relationships for the six outcomes are presented in the subsequent chapters.

### ***Methods of the systematic literature review***

#### **Search strategy**

Studies were identified through a systematic review of the literature. The following databases were searched from 1980 to 2000, except for CAB abstracts where the search was from 1987 to 2000:

- PUBMED
- Medline
- CAB Health and CAB Abstracts (including nutritional abstracts and reviews)
- The Cochrane Library (including DARE: Database of Abstracts and Reviews of Effects)
- Web of Knowledge (including Web of Science and ISI database)
- EMBASE

The search strategy was designed to be used initially in PUBMED and adapted to the other databases.

Free text terms used to search included (fruit\* OR vegetable\*) AND [(diet\* OR food habit\*); with coronary heart disease, ischaemic heart disease, cerebrovascular disorder, stroke, (lung OR colorectal OR stomach OR esophageal OR oesophageal) AND (neoplasm OR cancer)]; limited to human studies and not animals.

MeSH terms used included diet\*, food habit\*, fruit\* (not exploded to exclude nuts and seeds), vegetable\*; with coronary heart disease, ischaemic heart disease, cerebrovascular disorder, stroke, (lung OR colorectal OR stomach OR esophageal OR oesophageal) AND (neoplasm OR Cancer)); limited to human studies and not animals.

The database search was complemented by a comprehensive search for grey literature and other relevant material. This included a hand search of citations from books, reviews and citations of references already located. Published systematic reviews addressing fruit or vegetable intake and disease relationships were sought. Authors who had published key studies and reviews in the field were also approached to help identify any other studies, published or unpublished. Other nutritional experts in the field were also contacted for references to studies not identified by the database search process. These included WHO regional nutrition officers, coordinators of national fruit and vegetable promotion programmes and WHO nutrition collaborating centres worldwide. Messages requesting help in identifying data sources were posted on a nutritional epidemiology scientific mailing list ([NUTEPI@listserv.gmd.de](mailto:NUTEPI@listserv.gmd.de)). All retrieved references were entered into one large Endnote bibliographic file.

### **Process for selecting included studies**

Only papers or reports in English were considered (due to the language limitations of the candidate). Articles were rejected on initial screening only if the reviewer could determine from the title and abstract that the article was not a report of a study researching the relationship between fruit and vegetable intake and the selected disease outcomes.

The outcomes included in this systematic review were:

- Cardiovascular diseases: symptomatic heart disease, cerebrovascular disease and total circulatory disease. Studies of peripheral vascular disease, all-cause mortality and cardiovascular risk factors were excluded.
- Cancer: all histological types of the site-specific cancers were included but not reviewed separately.

When a paper could not be rejected with certainty from review of the abstract, the full text of the article was obtained for further evaluation. In each selected article, reference lists were checked and other articles that appeared appropriate to the review were retrieved.

### **Data collection**

An Excel spreadsheet was used to assess studies inclusion (or otherwise) into the review. The inclusion of studies was assessed independently by two assessors (the candidate and Dr Louise Causer), and differences between reviewers' results were

resolved by discussion. Reasons for exclusion were noted. Data abstraction was performed by the candidate and checked by the other assessor. Disagreements between reviewers' results were resolved by discussion and, when necessary, in consultation with a third reviewer. When several articles described the same study, the most complete article was used as the main source of data and the other articles used for supplemental information.

### **Inclusion criteria**

All studies that satisfied the following criteria were included in the systematic review of the literature:

- studies that measured dietary intake of fruit and/or vegetables;
- studies of vegetarians that measured food intake; and
- a special focus was placed on studies that explored associations of fruit and vegetable intake with diseases.

However, for completeness I have also included studies that used as their exposure variable proxy measures of intake derived from the measurement of intermediate variables (such as dietary fibre) or biological markers (such as carotenoids, folate, flavonoids, vitamins A and C not due to supplements) where there was a high correlation with the specific food type.

Studies were excluded if any one of the following criteria was satisfied:

- The measurement of risk was based solely on blood biochemical markers with no measure or estimate of dietary or nutrient intake;
- The study focus was on investigating the effect of non-dietary supplements;
- The outcome measure was prognosis, pre-cancerous lesions or pre-disease markers rather than incident cases or mortality;
- The statistical analyses of the study were not adjusted for major confounding factors such as age, sex and smoking.

### **Overview of studies identified by the systematic review**

Details of all studies included in the review of the literature are described in chapters 6 and 7, where the assessment of causality for each outcome is discussed. A short summary of the number of studies included in the systematic review is given in Table 5-1.

**Table 5-1      Summary of the studies included in the review of the literature**

Outcome	Case-control studies		Cohort studies	
	Number	Countries/sub-regions covered	Number	Countries/sub-regions covered
Ischaemic heart disease	Not assessed		28	USA, Europe (north) and Japan
Ischaemic stroke	Not assessed		22	USA, Europe (north) and Japan
Lung cancer	32	USA, Canada, China, Japan, Brazil, India, and Europe (north, south and east)	21	USA, Europe (north and south), Japan
Colorectal cancer	34	USA, Canada, China, Japan, Australia, Argentina, Uruguay, Russia, Singapore, Europe (north and south)	15	USA, Europe (north), Japan
Gastric cancer	32	USA, Canada, China, Japan, Korea, Mexico, Venezuela, Turkey, Europe (north and south)	14	USA, Europe (north), Japan
Oesophageal cancer	28	USA, China, Japan, India, South America, Europe (north and south)	4	China, Japan, Europe (north)

***Characteristics of the studies included in the literature review***

The studies included in the review of the literature differed in many ways, including:

- the type of study design;
- the sex, age range and ethnicity of the study population;
- the method and validity of measurement of the dietary exposure;
- the method of reporting the dietary exposure (qualitative versus quantitative);
- the period of follow up;
- the outcome measured;
- the range of intake of fruit and vegetables of the study population;
- the underlying disease risk of the population (i.e. high versus low); and
- the potential confounders that were adjusted for.

These differences often made results difficult to compare directly between studies. The fact that the majority of studies came from Europe, the United States and Japan is



another limitation as it restricts the generalisability of the data to the rest of the world. The details of the study differences are discussed in chapters 6 and 7.

### ***Methods used to obtain the summary estimates of relative risks***

To date there have been few reported meta-analyses of the association of fruit and vegetable intake with disease. In 1998, Law and Morris reported the results of a meta-analysis of published cohort studies of the relationship of different markers of fruit and vegetable consumption, including dietary intake of fruit and vegetables, on the risk of ischaemic heart disease, adjusted for other factors <sup>38</sup>. However, the results of this study were criticized by some researchers who suggested that potential residual confounding and heterogeneity among studies could have influenced the results <sup>265</sup>.

More recently, a group of researchers reported the results of an unpublished meta-analysis of previously published case-control and cohort studies. This has estimated the association of total fruit or total vegetable consumption with oesophageal, gastric and colorectal cancer <sup>267</sup>. The methodology used had limitations; studies were included if there was information necessary for the statistical analysis, but there was no assessment of study quality or potential confounding. The studies had measured fruit and vegetable intake in a range of ways, both quantitative and qualitative. If intake data were only from qualitative assessments (i.e. a subjective categorization into high versus low consumption), the amount of fruit and vegetables consumed in grams was estimated from average consumption in other studies or data sources, including FAO food balance sheets. The methodology used in this meta-analysis highlights the difficulties in obtaining an accurate summary measure of association for studies of fruit and vegetable intake.

### **Selection of studies for meta-analysis**

Considering the large variations among studies with regard to study design, study quality and measurement of both exposure and outcome, it appeared to be methodologically inappropriate and potentially misleading, to obtain summary measures of association by pooling results statistically from all the separate studies identified in the systematic review. This view has also been taken by other researchers who believe, given the quality and heterogeneity of the evidence for fruit and vegetable consumption and the substantial potential error in the measurement of diet, that meta-analyses are not appropriate for pooling observational studies and will only serve to

attenuate the error without exploring the heterogeneity which may be important in diet-disease relationships<sup>33 40 268</sup>.

In this study it was decided first to apply strict criteria to select only the best quality and most representative studies for the association of fruit and vegetable intake with each disease outcome. Only the studies meeting these criteria were then eligible for inclusion in a meta-analysis.

I applied the following selection criteria to the studies identified in the systematic review:

- Results from cohort studies were considered as more reliable evidence of association than results from case-control studies. Thus, case-control studies were excluded from the analysis.
- The sample size of the study was large and ideally representative of the population.
- The follow-up period was sufficiently long to expect an effect to be detected.
- The study population ideally included a broad age range.
- The methodology for data collection and analysis was robust and clearly documented.
- The study collected data on total fruit and vegetable consumption and not just by selected groups of fruit or vegetables (e.g. citrus fruit, green leafy vegetables, raw and cooked vegetables).
- Dietary measurement had been validated and was detailed enough to quantify fruit and vegetable consumption accurately (e.g. a food frequency questionnaire having >40 items of fruit and vegetables is likely to be better than one that includes only 4 items).
- Studies in which dietary assessment performed using one 24-hour recall or food record/diary were excluded.
- The statistical analyses were adjusted for important potential confounders.
- The information was available to enable the estimation of relative risk and confidence intervals with intake treated as a continuous variable for meta-analysis.

The number of studies that met the selection criteria for each outcome is given in Table 5.2.

**Table 5-2      Number of cohort studies meeting the selection criteria for inclusion in a meta-analysis**

Outcome	Number of cohort studies reviewed	Number of studies meeting selection criteria
Ischaemic heart disease	28	4
Ischaemic stroke	22	2
Lung cancer	21	4
Colorectal cancer	15	3
Gastric cancer	14	1
Oesophageal cancer	4	0

### Data preparation

In the GBD study, fruit and vegetable intake was treated as a continuous variable and expressed in grams per person per day (see chapter 3). The final relative risk estimates are expressed as the unit of change in relative risk associated with an 80 gram increase in fruit and vegetable consumption—this amount representing a recognized standard serving size <sup>13</sup>. When data from the selected studies were not presented in this format, I used the following methods:

Where food consumption was expressed in frequencies (e.g. number of servings per day), these were multiplied by 80 grams — considered to be a standard portion size <sup>13</sup> — to give daily intake in grams/day.

Where the relative risk estimates were reported for various increments in intake (e.g. for 100 grams or 1 gram increase in intake), the relative risk estimates were first transformed onto a log scale and then divided by the comparison difference to give the log relative risk per gram per day; these were then multiplied by 80 to give final estimates expressed as per 80 gram increase.

Where an overall relative risk was not reported for consumption over the entire population range, two methods were used to obtain the relative risk estimates. In method 1, I estimated the additional g/day for which the relative risks given applied (details are given in chapters 6 and 7 for each selected study). In method 2, the method of Greenland and Longnecker <sup>269</sup>, implemented in Stata 7, was used to estimate the weighted regression slope over the published relative risks, allowing for correlations due to a common reference category. This method uses all the published relative risks, and should coincide approximately with method 1 if the log relative risks are linear on consumption. When there is non-linearity the two methods will differ, with the second

giving the best “average” slope over the whole consumption range, while the first gives a better estimate of slope over a smaller consumption range. Where there is a tendency for risk reduction to be less marked at higher consumption levels, method 2 will give a more conservative estimate of the relative risk per consumption increase.

Standard errors were calculated on the log scale by taking the upper (log) confidence limit minus the (log) estimated relative risk and dividing this by 1.96; standard errors were also scaled in the same way as estimates to apply to an 80 g/day comparison difference.

## **Meta-analysis**

Where more than one study was identified using the selection criteria, I undertook a meta-analysis to combine estimates and obtain a summary estimate of the relationship between fruit and vegetable intake and the selected outcome<sup>270</sup>. The meta-analysis was performed using study log relative risks and the corresponding standard errors and implemented in Stata 7 (“meta” macro). Heterogeneity between studies was tested using the chi-squared statistic. The random effects result was pre-specified conditional on evidence of heterogeneity. When only two studies were available, fixed-effect meta-analysis was used. Forest plots, showing the results for individual studies, were prepared.

## ***Extrapolations of the relative risk estimates to the GBD study***

The studies used to derive relative risk estimates came mainly from Japan, the USA and Western Europe. It is likely that differences in factors that interact with fruit and vegetables also vary among populations. However, as these differences are not known, the same relative risk estimates were applied to all regions, assuming no interaction between the level of intake and sub-region on the associations. It is not possible to verify whether this assumption is true as the study populations covered by the literature reviews were from limited geographical areas, which did not allow sub-regional comparisons. While it is important to consider the issue of transferring relative risks across populations, this is likely to be a smaller source of uncertainty than how one defines and measures exposure in such epidemiological studies.

Many of the studies covered only limited age ranges, with most being from middle-aged or elderly populations. None of the studies were of children younger than 16 years of age. A low intake of fruit and vegetables in childhood would be expected to be a risk

factor for disease later in life<sup>271</sup>, but there is currently little evidence to support this. A previous review for the New Zealand burden of disease and injury study proposed that the age-specific relative risks for fruit-and-vegetable disease associations describes an inverted u-curve, which assumes that the relative risk is one at the extremes of age (<25 years and >75 years)<sup>19</sup>. The authors of the review argued that they do not expect individuals less than 25 years to be at risk given that the outcomes are chronic diseases, that such outcomes are rare in children, and that children have probably had insufficient duration of exposure. They also applied reduced relative risks to older age groups (i.e. applying a relative risk of one to everyone over 75 years) as there are high competing mortality risks at these ages.

Because there is currently little evidence for significant variations in relative risk by age and sex, the relative risk estimates were applied to both sexes and to all groups of people aged between 15 and 69 years. Although studies of fruit and vegetable intake have not quantified this there is, however, evidence from other, presumably intermediate, risk factors like obesity and blood pressure. This suggests that age attenuation is likely in relative risk at both extremes of age<sup>19</sup>. However, due to the current lack of information on how this would influence relative risks at varying intakes of fruit and vegetables, approximate age attenuations were thus applied as follows: relative risks were reduced by 25% for individuals aged 70–79 years and by 50% for those aged 80 years and over. Under the age of 15 years, a relative risk of 1 was applied.

### ***Steps to assess and reduce bias***

There are a number of generic methodological issues that could lead to the introduction of bias in nutritional epidemiology studies. The following paragraphs briefly describe confounding and the major sources of measurement, recall and selection biases common to such studies, with a particular focus on issues that are specific to conducting this systematic review of fruit and vegetables as a protective factor.

### **Confounding**

Well-known potential confounders of the association of fruit and vegetable intake with cardiovascular disease and cancer include, among others, sex, age and smoking. It is possible that a high intake of fruit and vegetables may be associated with other healthy

behaviour, for example lower consumption of saturated fat or non-smoking, that also have a protective effect on the selected outcomes.

In order to account for the potential effect of confounding on the relative risk estimates, all studies that were identified in the review of the literature must have performed some statistical adjustment for potential confounders. Most studies adjusted for the basic confounding factors, age and sex. The majority of recent studies also controlled statistically for a range of other variables including smoking, alcohol consumption, total energy intake, other foods and food constituents (including saturated fat intake for heart disease), body mass index, and vitamin supplementation. Some studies also adjusted for socioeconomic status, educational level, ethnicity, occupation and place of residence. The potential confounders that are specific to each of the selected disease outcomes are discussed in more detail in chapter 6. It is important to note that statistical adjustment for potential confounding implies accepting that the instruments used to measure these potential confounders did this reasonably well. This may not be the case for all potential confounders (e.g. energy intake or physical activity level). In addition, even where there is a high degree of statistical control for potential confounding, the possibility remains that part of the association estimated is due to uncontrolled (residual) confounding <sup>265</sup>.

Another method frequently used to take account of potential confounding is to restrict the study population. For example, some studies included only non-smokers when investigating the association of fruit and vegetable consumption with lung cancer. A disadvantage of this approach is that it limits the generalisability of the study findings.

### **Selection bias**

The issues related to selection bias in the studies reviewed for this project are similar to those of studies investigating other risk factor–disease relationships. For example, it is generally accepted that the selection of controls in case–control studies is likely to influence the study results. Study participation is usually high for cases but lower for controls; those who participate are more likely to be more health conscious, and thus perhaps consume more fruit and vegetables <sup>272</sup>.

The studies reviewed employed a variety of approaches to reduce selection bias. For example, many studies tried to match controls to their cases as closely as possible in

terms of age and sex. The generalisability of the results is also influenced by the source of controls with population-based controls being better than hospital-based controls.

## **Information bias**

### ***Exposure***

In the studies included in the review of the literature, data on dietary intake were collected using some form of diet history, food frequency questionnaire, 24-hour dietary recall(s) or food diary/food record. Details regarding the technical aspects and limitations of these methods of data collection were discussed in chapter 3. Measurement error is an issue in all studies of dietary exposure <sup>273</sup>. In general, this imprecision leads to a substantial attenuation of disease-exposure associations, such that relative risk, dose-response, and the extent to which there are thresholds in disease-exposure associations may be underestimated <sup>274</sup>.

Food frequency questionnaires are commonly used in nutritional epidemiology. However, most food frequency questionnaires can be criticized because of their limited ability to collect detailed accurate information on the intake of fruit and vegetables <sup>275</sup>. Very few instruments have been designed to study fruit and vegetable consumption specifically. Recent publications from the US Nurses Health Study and the US Health Professionals Study purporting to show no effect have been questioned as being unreliable as their food frequency questionnaire is inadequate to fully assess fruit and vegetable intake <sup>272</sup>.

Little is known of the measurement error structure for reported fruit and vegetable intake in FFQs. Many early estimates based on comparisons with different questionnaires or diet records had problems, underestimating both the degree of error and the correlation between the sources of errors <sup>276 277</sup>. Various problems are apparent. The level of measurement error is large compared with the true variation of intake in many study populations, there may be systematic bias in reporting at the individual level, and lack of independence of the measurement errors between the food frequency questionnaire and reference instrument <sup>278 279</sup>.

These factors may lead to considerably greater relative risk attenuation than has been previously realized, making modest decreases in relative risks difficult to detect <sup>280</sup>. The implications are that negative results of diet-disease studies may be misleading, and that controlling for a number of correlated dietary variables when exploring the

diet-disease association of a specific dietary item can lead to uninterpretable or unpredictable results.

Recall bias is a major problem in case-control studies. Where participants are asked to recall the dietary intake that they had in the past, recall bias may be present if the recall of previous dietary intake is influenced by disease status. In addition, when current diet is the exposure of interest in the study, dietary intake may have been affected by the disease process itself (e.g. reduction of food intake in individuals with oesophageal cancer). In some cases, surrogate interviewees (spouses or immediate family members) are asked to provide information for the cases and controls. This might also lead to misclassification bias.

A few studies reviewed for this project used a single 24-hour recall as their method of dietary measurement. A single 24-hour recall has a high degree of intra- to inter-individual variability and cannot accurately represent an individual's usual intake <sup>281</sup>. This may lead to important misclassification error and may bias the observed risk estimates towards the null value. This is likely to be non-differential bias <sup>282</sup>.

A further difficulty with the methodologies of the studies reviewed in this thesis is the assumption of unchanged dietary intake over long follow-up periods. This again may lead to measurement error in long-term cohort studies due either to changes in dietary habits over time or to dietary recall of past exposure.

The studies reviewed also raised the issue of the validity and reliability of extrapolating results from studies based on micronutrient intakes or status to the effect of intakes of fruit and vegetables. In this review, I have tried to select only studies with data based on food consumption rather than biomarkers of intakes. Where no appropriate food-exposure data existed, it was decided to include proxy nutrients (such as vitamin C from diet) when this was validated by consumption studies. This approach was necessary as there were a large number of studies that framed their hypotheses in terms of specific nutrients, and reported only associations with these nutrients. For example, studies such as the EPIC-Norfolk study <sup>283</sup> have tried to reduce the subjective nature of dietary assessment by using biological indicators such as plasma ascorbic acid, which they correlated with food intake. The use of plasma ascorbic acid measurement is thought to represent dietary intake in the preceding few weeks and may overcome some of the issues involved with dietary assessment <sup>284</sup>. However, biomarkers are also prone



to measurement error that could also explain the lack of consistency in studies in which such biomarkers (including vitamin C) have been used. In addition, these proxy measures of intake are not ideal as it is clear that any beneficial effect of fruit and vegetables involves many nutrient and non-nutrient factors. They would tend to underestimate the impact of a mixed intake of fruit and vegetables.

Finally, there is substantial variability among studies in the categorization of exposure groups, not only in terms of what constitutes the “fruit and vegetables” measured (e.g. only citrus fruit, only green leafy vegetables or total fruit and vegetables), but also the actual levels of intake within these groups (e.g. quintiles versus quartiles versus tertiles, or “rarely” vs “frequently”). Exactly what level of intake represents a high or a low intake will vary significantly among populations and will be influenced by the method of data collection. This literature review does not comment on the association of disease risk with specific fruit and vegetables, although several studies have attempted to do this in their analyses.

### ***Outcome***

The best studies reviewed for this project were those that utilized more than one method to identify cases to avoid any losses to follow-up in the final analysis. The methods used included death certificates, hospital records, living relatives, self-report, and cancer registries.

### ***Summary***

This chapter presents the methods used for conducting a systematic review and meta-analysis of fruit and vegetables and six disease outcomes- ischaemic heart disease, stroke, lung, colorectal, gastric and oesophageal cancer. This provided a means to obtain evidence on the direction and size of the relationship between fruit and vegetable consumption and the selected disease outcomes in a form appropriate for the Comparative Risk Assessment methods being used in the GBD study. The results for each of the six disease outcomes are given in chapters 6 and 7. The methods and results of how these relative risk estimates are used in the calculation of the burden of disease due to low fruit and vegetable consumption is presented in chapter 8.

## **Chapter 6 The association between fruit and vegetable consumption and cardiovascular disease**

This chapter presents the results of the systematic review and meta-analysis for the relationship between fruit and vegetable intake and ischaemic heart disease and stroke.

### ***Ischaemic heart disease***

#### **Detailed description of the studies included in the review of the literature**

28 papers were identified that described prospective studies investigating the association of ischaemic heart disease risk with fruit and vegetable consumption. Details of the study characteristics are given in Table 6-1. The study populations were all from the United States, Europe (United Kingdom, Norway, Sweden, Finland, The Netherlands) and Japan. Five studies gave rise to more than one report; 14 studies included men and women, 9 studied men only and 5 studied women only. The follow-up time varied between 4 and 25 years. The method used to measure fruit and vegetable intake differed considerably among studies, ranging from one 24-hour dietary recall and a seven-day prospective weighed food diary to a variety of food-frequency questionnaires.

Sixteen of the 28 studies reported a statistically significant inverse association between intake of fruit and vegetables and ischaemic heart disease. Thirteen of these showed an association with food intake, while the other three showed an association with a proxy diet measure that was correlated with fruit and vegetable intake. Nine further studies also reported an inverse association; seven of these were not statistically significant; two others did not report confidence intervals or measures of statistical significance.

**Table 6-1 Summary of cohort studies reporting association between intake of fruit and vegetables and ischaemic heart disease**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetables	Association with diet proxy
Bus and bank workers, London and South England <sup>285</sup>	M	30-67	337	Mortality(26), Incidence (45)	10-20 years	7 day weighed diary		Inverse, not statistically significant (fibre)
Japanese general population survey (1965 census) <sup>286</sup>	M+F	40+	265 118	Mortality (n/a)	16 years	Crude-Not clear	Inverse, statistically significant (unadjusted)	
Gothenburg women, Sweden <sup>287</sup>	F	38-60	1 462	MI (23), Mortality (75)	12 years	24 hour recall		No association (Vitamin C)
Rancho Bernardo Cohort, California <sup>288</sup>	M+F	50-79	859	MI and Mortality	12 years	24 hour recall		Positive, not statistically significant (potassium)
The Adventist Health Study, California <sup>289</sup>	M+F	25+	26 473	MI(134), Mortality(260)	6 years	65 item food frequency questionnaire	Positive, not statistically significant	
Caerphilly Ischaemic Heart Disease Study <sup>290 291</sup>	M	45-59	2 423	Incidence (148), Mortality(132)	5 years (10 years)	7 day weighed diet intake		Inverse, No CI (Vit C, Magnesium)
Zutphen Elderly Study, the Netherlands <sup>292</sup>	M	65-84	805	MI(38),Mortality(43)	5 years	Cross check dietary history	Inverse, not statistically significant	Inverse (flavonoids)
The Seven Countries Study, Europe, Japan and USA <sup>293</sup>	M	40-59	12 763	Mortality (1555)	25 years	Weighed diet intake (1-7 day records)	Inverse, statistically significant (vegetables)	
Finnish mobile clinic health examination survey cohort <sup>294, 295</sup>	M+F	30-69	5 133	Mortality (244)	14 years	Repeated diet history	Inverse, statistically significant	
Western Electric Company Study, Chicago <sup>296</sup>	M	40-55	1 556	Mortality (231)	24 years	2x Cross check diet history and food frequency questionnaire		Inverse, not statistically significant (Vit C, B-carotene)
Massachusetts Health Care Panel Study <sup>297</sup>	M+F	66+	1 299	Mortality (48)	4.75 years	43 item food frequency questionnaire	Inverse, statistically significant	
Elderly cohort, Dept of Health and Social Security Survey, United Kingdom <sup>229</sup>	M+F	65+	730	Mortality(182)	20 years	7 day weighed food record		Inverse, not statistically sig (Vit C)



Table 6-1 (continued) Summary of cohort studies reporting association between intake of fruit and vegetables and ischaemic heart disease

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit and/ or vegetables	Association with diet proxy
Iowa Women's Health Study, USA <sup>298, 299</sup>	F	55-69	34 486	Mortality (242)	7 years	127 item food frequency questionnaire	Inverse, statistically significant for some vegetables	Inverse, not statistically significant (vitamin C)
Vegetarians and Health Conscious People, United Kingdom <sup>300</sup>	M+F	16+	10 771	Mortality (350)	16.8 years	Crude food frequency questionnaire	Inverse, statistically significant	
Vegetarians and Health Conscious Individuals Study II, United Kingdom <sup>301</sup>	M+F	16-79	10 802	Mortality (64)	13.3 years	food frequency questionnaire	Inverse, statistically significant	
Smokers in ATBC study, Finland <sup>302</sup>	M	50-69	21 930	Incidence (818) mortality (581)	6.1 years	Diet history	Inverse, statistically significant	
Rotterdam study, the Netherlands <sup>303</sup>	M+F	55-95	4 802	MI (124)	4 years	food frequency questionnaire		Inverse, statistically sig (B-carotene)
Scottish Heart Health Study <sup>304</sup>	M+F	40-59	11 629	Incidence (296)	6-9 years	60 item food frequency questionnaire		Inverse, statistically significant (vitamin C, B-carotene, fibre)
EPIC-Norfolk, United Kingdom <sup>233</sup>	M+F	45-79	19 496	Mortality (123)	4 years	food frequency questionnaire and plasma ascorbic acid analysis		Inverse, statistically significant (vitamin C)
NHANES 1 epidemiological follow-up study, USA <sup>305</sup>	M+F	24-74	11 924	Mortality (793)	19 years	24 hr recall and food frequency questionnaire	Inverse, statistically significant	
Nurses Health Study, USA <sup>230</sup>	F	34-59	87 245	MI(437), Mortality(115)	8 years	Repeated food frequency questionnaire		Inverse, not statistically sig. (vitC)
Nurses Health study, USA <sup>306</sup>	F	34-59	39 876	MI (126)	5 years	food frequency questionnaire	Inverse, not statistically sig.	
Health Professionals Follow-up Study, USA <sup>307</sup>	M	40-75	43 757	MI: Nonfatal(511) and fatal (229)	6 years	Repeated food frequency questionnaire	Inverse, statistically significant	
Health Professionals Follow-up study, USA <sup>308</sup>	M	40-75	15 220	MI (387)	12 years	food frequency questionnaire repeated 2 yearly	Inverse, statistically significant	
Nurses and Health Professionals Follow-up studies, USA <sup>309</sup>	M+F	F: 34-59 M: 40-75	F: 84 251 M: 42 148	Incidence F: 1127; M: 1063	8-14 years	131 item food frequency questionnaire (intervals)	Inverse, statistically significant	

## Confounding

Before assessing the impact of fruit and vegetable consumption, it is important to consider some methodological issues. A high intake of fruit and vegetables may be associated with other healthy behaviours, such as not smoking. High intakes of fruit and vegetables may also displace other foods from the diet, causing reduced intake of potentially harmful substances such as saturated fat and salt. Results from the Dietary Approaches to Stop Hypertension (DASH) trial suggested that changes in dietary fats do not necessarily accompany an increase in fruit and vegetable intake. As noted previously, in that trial, hypertensive participants were fed a control diet for three weeks and then randomized to receive for eight weeks either the control diet, a diet rich in fruit and vegetables, or a combination diet rich in fruit and vegetables, and reduced in saturated fat, fat and cholesterol <sup>251 252</sup>. Both the combination diet and the fruit-and-vegetables diet significantly reduced systolic and diastolic blood pressure. After eight weeks, 70% of the participants on the combination diet had a normal blood pressure, 45% of those on the fruit and vegetable diet, and 23% of those on the control diet. The fruit and vegetable diet produced few changes in blood lipids but had an independent effect of reducing coronary heart disease risk. Sodium/salt is perhaps an under acknowledged potential confounder for ischaemic heart disease and stroke. Persons who consume more salads may consume less salt. The lack of evidence of confounding by salt mainly relates to the difficulty of measuring sodium exposure in individuals—not to its intrinsic importance.

Most of the studies reviewed adjusted for some potential confounding factors known to be associated with the risk of cardiovascular disease. All adjusted for age, and most studies adjusted for sex and smoking. Very few of the older studies had adequately addressed the issue of confounding and this cannot be discounted as an explanation for an observed association in some studies. However, most recent studies have dealt with a comprehensive range of confounding factors, including the majority of the following: smoking, alcohol, total energy intake, saturated fat intake, cholesterol, body mass index, hypertension, diabetes, physical activity, hormone replacement therapy, educational status or social class, and nutritional supplement use. Measurement of some of these candidate confounders will potentially have substantial error (e.g. energy intake).

## **Summary**

In summary, the review of the literature suggests that there is a strong inverse relationship between fruit and vegetable intake and cardiovascular disease in over half the prospective observational studies in many different populations. The relationship remains after some adjustment for confounding. This result needs to be interpreted in the light of findings with regard to the more favoured diet hypotheses. In a review of the evidence for the classic diet–heart hypothesis, Willett found a positive association with saturated fat intake in only 2 of the 12 cohort studies reviewed, and a positive association with cholesterol intake in two <sup>190</sup>.

## ***Ischaemic stroke***

It was decided to limit the analysis to ischaemic stroke as most of the studies identified in the systematic review had only considered outcomes of ischaemic stroke. The few studies that had analysed ischaemic and haemorrhagic stroke separately provided insufficient evidence to draw any conclusions on the association of differential outcomes with fruit and vegetable intake. Furthermore, it is more biologically plausible that the relationship of fruit and vegetable protection is with ischaemic stroke.

## **Detailed description of the studies included in the review of the literature**

As with ischaemic heart disease, evidence from case–control and ecological studies was not reviewed because the number of cohort studies identified was sufficiently high (cohort studies represent a stronger study design), and because there was a consistent pattern among studies. Overall, the evidence suggests a strong protective effect of fruit and vegetable consumption on ischaemic stroke risk.

Twenty-two references to prospective studies of the association between stroke and the consumption of fruit and vegetables were identified. The study characteristics are shown in Table 6-2. In summary, the study populations were all from China, Europe (Finland, the Netherlands, Norway, Sweden, the United Kingdom), Japan or the United States. Three of the studies gave rise to more than one report. Ten studies had populations of men and women, eight studied men only and four studied women only. The follow-up period varied between 5 and 28 years. The method used to measure dietary intake of fruit and vegetables also varied considerably, including postal diet survey, 24-hour dietary recall, seven-day prospective weighed diet record, and various food-frequency questionnaires of differing length and quality.

Fourteen studies showed a statistically significant inverse association between the intake of fruit and vegetables and stroke. Six studies showed an association with food, while the other eight showed an association with a nutrient considered to be a proxy for fruit and vegetable intake.



**Table 6-2 Summary of cohort studies reporting measures of association between intake of fruit and vegetables and stroke**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetables	Association with diet proxy
Norwegian dietary postal survey <sup>310</sup>	M+F	45–74	16 713	Mortality (438)	11.5 years	Postal diet survey		Inverse, statistically significant (vitamin C)
Japanese general population survey (1965 census cohort) <sup>286</sup>	M+F	40+	265 118	Mortality (n/a)	16 years	Crude (not specified)	Positive, not statistically significant	
Shibata Study, Rural Japan (Yokoyama, 2000)	M+F	40+	2 121	CVA (109)	20 years	Food frequency questionnaire and serum vitamin C		Inverse, statistically significant (vitamin C) infarction and haemorrhagic stroke
Gothenburg women, Sweden <sup>287</sup>	F	38–60	1 462	CVA (13)	12 years	24 hour recall		No significant correlation (Vitamin C)
Rancho Bernardo Cohort, California <sup>311</sup>	M+F	50–79	859	Mortality (24)	12 years	24 hour recall		Inverse, statistically significant (dietary potassium)
Hawaiian men of Japanese Descent <sup>312</sup>	M	45–68	7 591	CVA (408)	16 years	24 hour recall		Inverse (dietary potassium)
Men in Shanghai, China <sup>313</sup>	M	45–64	18 244	CVA mortality (245)	5-8 years	food frequency questionnaire	No association	
Framingham study, USA <sup>314</sup>	M	45–65	832	Incident stroke (97)	20 years	24 hour recall	Inverse, statistically significant	
Zutphen study, the Netherlands <sup>315</sup>	M	50–69	552	CVA (42)	15 years	Repeated cross check dietary history	Inverse, not statistically significant	Inverse statistically significant (flavonoids)
Finnish mobile clinic health examination survey cohort <sup>316</sup>	M+F	30–69	9 208	Mortality (244)	28 years	Repeated diet history	Inverse, statistically significant (sub groups)	
Elderly cohort, Department of Health and Social Security Survey, United Kingdom <sup>229</sup>	M+F	65+	730	Mortality (124)	20 years	7 day weighed food record		Inverse, statistically significant (vitamin C)
Western Electric Company Study, Chicago <sup>231</sup>	M	40–55	1 556	CVA (222)	24 years	2x Cross check diet history and food frequency questionnaire (participant/ homemaker)		Inverse not statistically significant (Vitamin C and B-carotene)



**Table 6-2 (continued)**  
**stroke**

**Summary of cohort studies reporting measures of association between intake of fruit and vegetables and**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetables	Association with diet proxy
Iowa Women's Health Study, USA <sup>317</sup>	F	55–69	34 492	Mortality (131)	10 years	127- item food frequency questionnaire		No association (flavanoids)
Cohort of Vegetarians and Health Conscious People, United Kingdom <sup>300</sup>	M+F	16+	10 771	Mortality (147)	17 years	Crude food frequency questionnaire	Inverse, statistically significant	
Smokers in ATBC study, Finland <sup>318</sup>	M	50–69	26 593	Cerebral infarct (736) Haemorrhagic stroke (178)	6.1 years	Diet questionnaire		Inverse, statistically significant (B-carotene)
NHANES 1 epidemiological follow-up study, USA <sup>305 319</sup>	M+F	24–74	9 805	Stroke events (927)	19 years	24-hr recall and food frequency questionnaire	Inverse, statistically significant	Inverse, statistically significant (dietary potassium)
Nurses Health study, USA <sup>306</sup>	F	34–59	39 876	Incidence CVA (160)	5 years	food frequency questionnaire	Inverse, not statistically significant (all CVD)	
Nurses Health Study, USA <sup>320</sup>	F	34–59	87 245	Incidence CVA (345)	8 years	Repeated food frequency questionnaire	Inverse, statistically significant	
Health Professionals Follow-up study, USA <sup>218, 321</sup>	M	40–75	43 738	CVA (328): Ischaemic (210), haemorrhagic (70)	8 years	Repeated food frequency questionnaire		Inverse, statistically significant (dietary potassium); positive not significant (vitamin C)
Nurses and Health Professionals Follow-up studies, USA <sup>322</sup>	M+F	F 34–59 M 40–75	F 75 596 M 38 683	Ischaemic stroke incidence: F 366, M 204	8-14 years	Repeated food frequency questionnaire at intervals	Inverse, statistically significant	

## **Confounding**

As with ischaemic heart disease, the observed protective association between fruit and vegetables and stroke could, in theory, be explained by confounding. All studies included in the literature review adjusted for age and sex, and most recent studies reviewed also dealt with a comprehensive range of major measured confounders. However, very few of the older studies had adequately addressed the issue of confounding and this cannot be discounted as an explanation for an observed association in some studies.

## **Summary**

There is a strong inverse relationship between the level of fruit and vegetable consumption and stroke risk in prospective observational studies in many populations. The relationship persists after adjustment for major confounders.

## ***Estimating Relative Risks***

This section describes, for each selected outcome, the studies that were chosen based on the selection criteria for meta-analysis outlined, and the final estimates of relative risks derived.

## **Meta-analysis of the association of fruit and vegetable intake with ischaemic heart disease**

Details of the cohort studies that most closely met our selection criteria (discussed in chapter 5) are given in Table 6-3. The EPIC-Norfolk study <sup>233</sup> was included even though it presents results in relation to plasma vitamin C, because plasma vitamin C measurements (available for the whole cohort) were relatively well correlated with fruit and vegetable intake (available from a 7-day food record analysed for a subset of the cohort) and because of the high quality of the methods used to collect and analyse data.

**Table 6-3      Relative risk estimates for the association between ischaemic heart disease and fruit and vegetable consumption considered for the CRA project**

Study population	Sex (age range)	Outcome	RR (95% CI) per 80 g/day increase in fruit and vegetable intake	
Nurses Health and Health Professional Follow-up studies, USA <sup>309</sup>	M+F (34–75 yrs)	MI incidence	0.96	(0.94–0.99)
EPIC Norfolk, United Kingdom <sup>233</sup>	M+F (45–79yrs)	Mortality	0.54	(0.40–0.74)
Finnish Mobile Clinic Health Examination Study <sup>294</sup>	M+F (30–69yrs)	Mortality	0.964	(0.930–0.999)
Massachusetts Health Care Panel Study, USA <sup>297</sup>	M+F (>66 years)	Mortality	0.54	(0.35–0.84)

**Data transformation**

Fruit and vegetable intake in the Nurses Health and Health Professional’s Follow-up studies (NHS/HPFS), EPIC Norfolk and the Finnish Mobile Clinic Studies were treated as continuous variables. The NHS/HPFS Study gave the relative risk in terms of one additional serving per day, which were converted as 80 g/day (assumed to be one standard serving); The EPIC Norfolk and Finnish Mobile Clinic Study reported relative risk estimates for 50 g and 1 g increase in intake respectively. Thus, the relative risk estimates were transformed to give final estimates expressed as per 80 g/day increase.

For the Massachusetts Health Care Panel Study (data analysed as quartiles of intakes), the two methods described in chapter 5 were used to estimate the relative risks. With method 1, I estimated the additional g/day for which the relative risks given applied. The study gave exposure quartiles with mid-points at 32, 88, 138 and 190 g/day (the last estimated as the lower limit, 164, plus half the previous category interval), and reported relative risks for the two latter categories compared with the first quartile. A difference of 55 g between adjacent quartiles was assumed, which gives exposures of approximately 30, 85, 140 and 195 g/day. This approximation yielded comparable relative risks per 55g difference whichever of the two reported relative risks was converted, and the relative risk reported for the 4<sup>th</sup> vs 1<sup>st</sup> quartile was used, which was expressed as a difference in exposure of 3 x 55 = 165 g/day. The method of Greenland and Longnecker (method 2) was then used to estimate the weighted regression slope over the published relative risks, allowing for correlations due to common reference

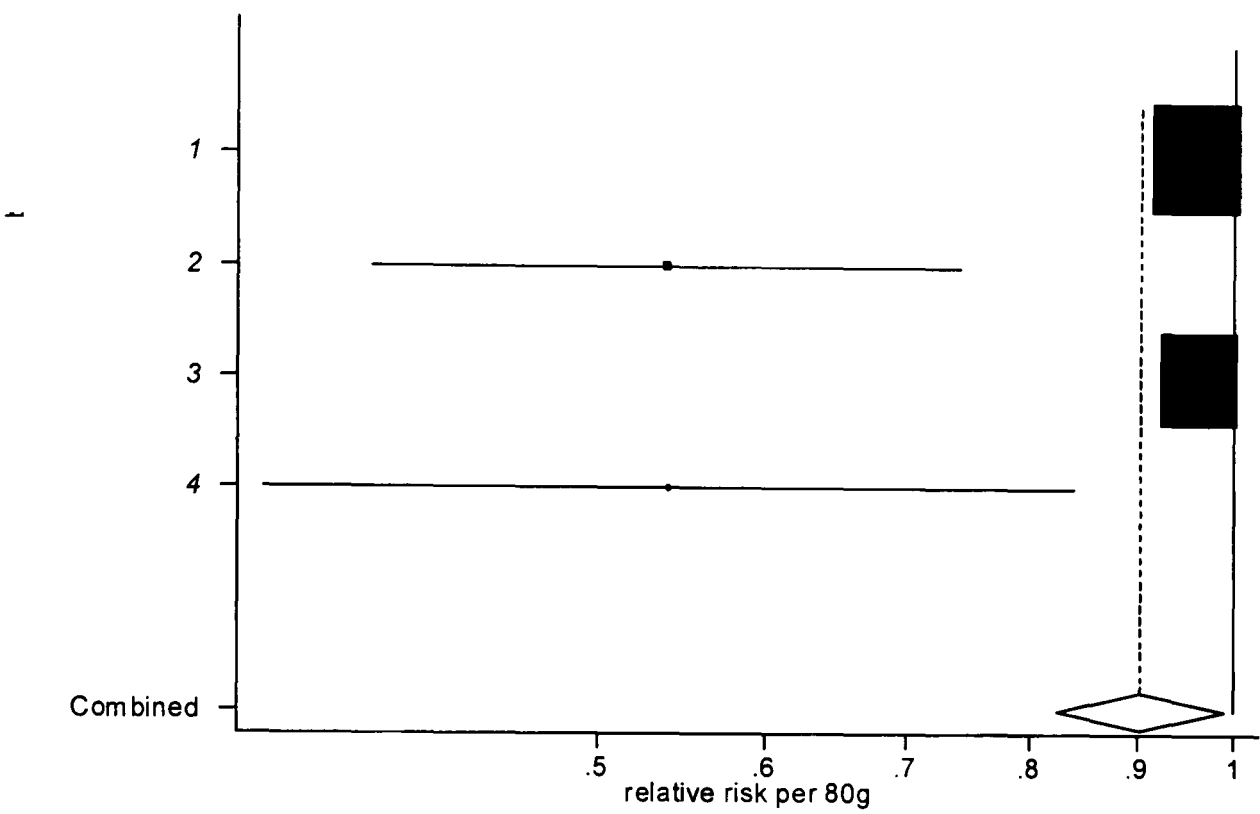
category. Because of its advantages (see chapter 5), method 2 was chosen to obtain the final estimates for inclusion in the meta-analysis.

### **Meta-analysis**

Meta-analysis was used to pool relative risk estimates using the method described in chapter 5. The test of heterogeneity gave a chi-squared value of 19.044 (df= 3;  $P<0.001$ ). The resulting variation between studies suggests that it is inappropriate to pool estimates according to the fixed effects method. Using random effects meta-analysis, the pooled relative risk estimate was 0.903 (95 % confidence intervals 0.824-0.989) for an 80g/day increase in fruit and vegetable consumption. The random effects results are shown in Figure 6-1.

The figure shows that there is marked heterogeneity in the best available evidence on the effects of fruit and vegetable consumption on the risk of ischaemic heart disease. The sources of this heterogeneity are currently not understood scientifically, and there is, therefore, no fully satisfactory means for arriving at a summary effect estimate. The random effects model used here provides a pragmatic interim solution to summarizing this evidence, pending better scientific understanding of the underlying relationships. The derived effect size seems plausible in the light of the consistency of the study findings but it remains subject to substantial uncertainty—only some of which derives from the statistical uncertainty associated with the four studies included.

**Figure 6-1     Random effects meta-analysis of the association of fruit and vegetable intake with ischaemic heart disease**



Key to studies:

1 = NHS/HPFS; 2 = EPIC Norfolk Study; 3 = Finnish Mobile Clinic Health Examination Study; 4 = Massachusetts Health Care Panel Study

**Meta-analysis of the association of fruit and vegetable intake with ischaemic stroke**

Only two cohort studies met the selection criteria for meta-analysis. These are summarized in Table 6-4.

**Table 6-4     Relative risk estimates for the association between stroke and fruit and vegetable consumption considered for the CRA project**

Study Population		Sex (age)	Outcome	RR (95% CI) per 80 g/day increase in fruit and vegetable intake	
Zutphen Study, the Netherlands		M (50–69)	Incidence CVA	0.87	(0.49–1.53)
NHS/HPFS Study, USA <sup>309</sup>		M + F (34–75)	Incidence ischaemic stroke	0.96	(0.94–0.99)
F	female; M	male			

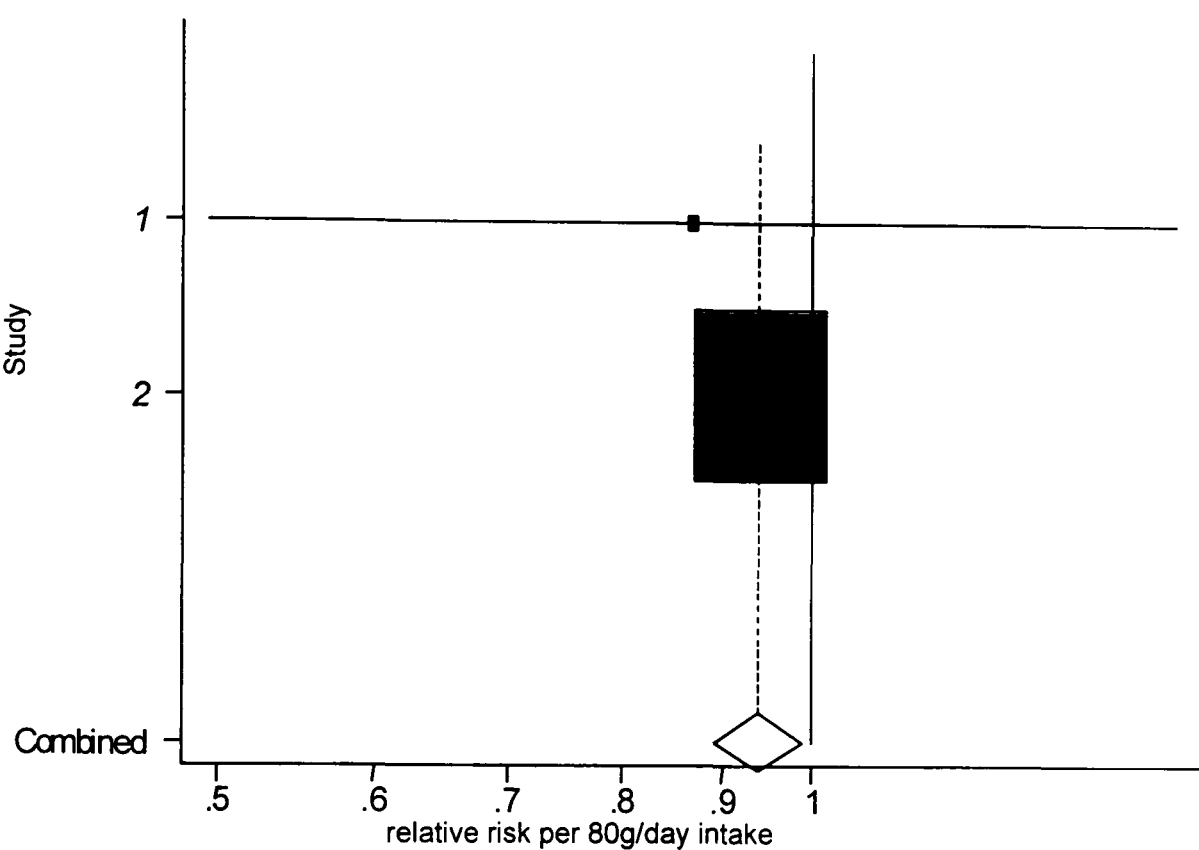
### **Data transformation**

The NHS/HPFS gave the relative risk in terms of one additional serving per day, which were converted as 80 g/day. As the Zutphen Study did not give a single estimate of linear (log) relative risk per consumption, the relative risk estimates were derived using the two methods described earlier for ischaemic heart disease. Since vegetable and fruit consumption were separately analysed, the relative risk for vegetable consumption was used: it seems to us likely that vegetable and fruit consumption would confound each other, so that what is reported as a purely “vegetable” effect includes the effect of fruit eaten by vegetable consumers. Since a diet of only fruit is rare, the vegetable effect reported was assumed to be similar to that which would have been reported for a combined fruit and vegetable diet (although this may underestimate the effect). Method 2, of Greenland and Longnecker <sup>269</sup>, gave an almost identical estimate to Method 1, which used a consumption difference of the 4<sup>th</sup> vs 1<sup>st</sup> quartile (249.9 - 128.1 = 121 g/day) for the 0.82 relative risk (vegetables) as the basis for the estimate. Results based on method 2 are therefore reported here.

### **Meta-analysis**

Relative risk estimates were combined using fixed-effect meta-analysis as the random effects could not be estimated. The pooled relative risk estimate was 0.939 (95% CI 0.892–0.989) for an 80 g/day increase in fruit and vegetable consumption. The results are shown in Figure 6.2.

**Figure 6-2     Fixed effects meta-analysis of the association of fruit and vegetable intake with ischaemic stroke**



Key to studies:

- 1= Zupthen Study; 2= NHS/HPFS

**Summary**

The relative risk estimates for ischaemic heart disease and stroke, and 95% confidence intervals are summarized in Table 6-5. Estimates are expressed as the change in relative risk associated with an 80 g increase in daily fruit and vegetable intake.

**Table 6-5     Relative risks with increased fruit and vegetable consumption (95% confidence intervals) by age group**

Outcome	Age group (years)							
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
Ischaemic heart disease	1.00	1.00	0.90 (0.82-0.99)	0.90 (0.82-0.99)	0.90 (0.82-0.99)	0.90 (0.82-0.99)	0.93 (0.85-1.01)	0.95 (0.87-1.03)
Ischaemic stroke	1.00	1.00	0.94 (0.89-0.99)	0.94 (0.89-0.99)	0.94 (0.89-0.99)	0.94 (0.89-0.99)	0.95 (0.91-1.00)	0.97 (0.92-1.02)

Unit of change in risk: change per 80 g/day increase in fruit and vegetable intake

As discussed earlier, the relative risks are applied to all sub-regions and to both males and females. Assuming age attenuation at the extremes of age, these relative risks apply for individuals aged 15-69 years. For older adults the relative risks were reduced by a

quarter for ages 70–79, and by half for over 80 years of age. Under the age of 15 years a relative risk of 1 was applied.

The following chapter will present the equivalent results for the relationship between fruit and vegetable intake and four cancer outcomes.



## **Chapter 7 The association between fruit and vegetable consumption and selected cancers**

This chapter examines the evidence from available literature on the association between fruit and vegetable consumption and certain cancers. These are cancer of the lung, stomach, colon and rectum, and oesophagus.

### ***Lung cancer***

The literature review identified 21 cohort and 32 case–control studies that examined the association of fruit and vegetable intake with the risk of lung cancer incidence and mortality. Details of the studies are provided in Table 7-1 and Table 7-2. Overall, the evidence appears to support an inverse relationship between fruit and vegetable consumption and lung cancer risk (both incidence and mortality).

### **Cohort studies**

The cohort studies identified were conducted in a range of countries including the United States, the Netherlands, Finland, Japan and other southern and northern European countries participating in the Seven Country Study. The study populations were not necessarily nationally representative as some studies were limited to religious groups or those with particular lifestyle characteristics <sup>323 300</sup>, specific occupational groups <sup>324 325</sup>, or very narrow age groups such as the elderly <sup>326</sup>. Three studies from the United States analysed national survey data and are therefore likely to be more nationally representative. Very few studies were of young people.

Of the 21 cohort studies it should be noted that five of the study populations were each used in more than one study. The studies differed in their analysis by reporting different risk factors (i.e. carotenoids vs fruit and vegetables) or using different outcome measures (mortality versus incidence).

Of the 21 cohort studies, 12 studied incidence of lung cancer as the outcome measure while eight studied lung cancer mortality. Follow-up periods varied between 4–25 years, with 16 studies having follow-up periods longer than 10 years. Twelve of the studies investigated populations of men and women, seven studies had male-only cohorts and two studies were entirely female. Most studies have pooled results for men and women, the explanation being that the number of lung cancer cases in women is too small to justify a meaningful separate analysis. Only a few studies have analysed

men and women separately, usually where the entire study cohort was either men or women. More detailed characteristics of all studies are given in Table 7-1.

Of the 21 cohort studies, 11 showed a statistically significant inverse association between a diet high in fruit or vegetables (in one of these the association was significant for dietary carotenoids) and lung cancer. The remainder of the studies showed an inverse association that was not statistically significant. In some studies with non-significant results for total fruit and vegetables, sub-analyses were reported as having significant associations.

Of particular interest are studies of lung cancer incidence and mortality that considered non-smokers, former smokers and smokers separately in the analyses. It appears that the benefit conferred through a high intake of fruit and vegetables more often reaches statistical significance in current smokers than in non-smokers (however, confidence intervals are often large and overlap). In summary, eight of the cohort studies reviewed for this project stratified the analyses by smoking status. Three of these showed a significant relationship between fruit and vegetable consumption and lung cancer incidence in smokers but not in non-smokers (but for one of these, the relative risks of both groups were similar)<sup>17 323 327</sup> while only one study showed an inverse relationship in non-smokers only<sup>328</sup>. The other studies showed non-significant results<sup>324 329 330 331</sup> for both smokers and non-smokers. These results would tend to agree with the hypothesized biological mechanisms for the benefits of fruit and vegetables in lung cancer through late stage modification of carcinogenesis following an initial carcinogen exposure. Intuitively it seems reasonable that the effect of fruit and vegetables may be different between these two groups; however further research is needed considering the current inconsistencies in findings, including exposure among non-smokers to environmental tobacco smoke and the range of other lung cancer risk factors.

**Table 7-1 Summary of cohort studies reporting association between intake of fruit and vegetables and lung cancer**

Study population(s)	Sex	Age range	Study size	No. of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake	Association with diet proxy
National Health Interview survey, USA <sup>332</sup>	M+F	Nationally representative	20 004	Mortality (158)	8.5 years	59 item food frequency questionnaire	Inverse, not statistically significant	
Japanese general population survey (1965 census cohort) <sup>286 333</sup>	M+F	40+	265 118	Mortality (1 917)	16 years	Crude—not clear	Inverse, statistically significant (men)	
Volunteers from 25 states (American Cancer Society Cohort), USA <sup>334</sup> ,	M+F		1 000 000	N/a	11 years	Not clear	Inverse, not statistically significant	
Iowa Women's Health Study, USA <sup>329</sup>	F	55–69	41 387	Incidence (179)	4 years	127 item food frequency questionnaire	Inverse, statistically significant	
Lutheran Brotherhood Insurance Cohort, USA <sup>335</sup>	M		17 818	Mortality (219)	20 years	Diet questionnaire	Inverse, not statistically significant	
Leisure World Cohort, California <sup>326</sup>	M+F	50–79	11 580	Incidence (164)	8 years	24 hour recall	Inverse, not statistically significant (women)	
The Adventist Health Study, California <sup>323</sup>	M+F	25+	34 198	Incidence (61)	6 years	65 item food frequency questionnaire	Inverse, not statistically significant	
Zutphen Study, the Netherlands <sup>336, 337</sup>	M	40–59	561	Mortality (54)	25 years	Repeated cross check dietary history	Inverse, statistically significant	
Finnish mobile clinic health examination survey cohort <sup>327</sup>	M	20–69	4 538	Incidence (117)	20 years	100 item food frequency questionnaire	Inverse, statistically significant	
Finnish mobile clinic health examination survey cohort <sup>328</sup>	M+F	15–99	9 959	Incidence (151)	24 years	100 item food frequency questionnaire	Inverse, statistically significant	Inverse, statistically significant (flavonoids)
The Netherlands Cohort Study <sup>331</sup>	M+F	55–69	120 852	Incidence (1 074)	6.3 years	150 item food frequency questionnaire	Inverse, statistically significant	



**Table 7-1 (continued) Summary of cohort studies reporting association between intake of fruit and vegetables and lung cancer**

Study population(s)	Sex	Age range	Study size	No. of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake	Association with diet proxy
NHANES 1 epidemiologic follow-up study, USA <sup>17</sup>	M+F	25–74	10 068	Incidence (248)	19 years	24-hour recall and food frequency questionnaire	Inverse, statistically significant	
Cohort of Vegetarians and Health Conscious People, United Kingdom <sup>300</sup>	M+F	16+	10 771	Mortality (59)	16.8 years	Crude food frequency questionnaire	Inverse, not statistically significant	
Smokers in ATBC study, Finland <sup>338</sup>	M	50–69	27 110	Incidence (791)	6.1 years	Diet history	Inverse, statistically significant	
3 Cohorts, Norway <sup>339</sup>	M+F	N/a	16 713	Incidence (168)	11.5 years	food frequency questionnaire	Inverse, not statistically significant	
Seven Countries Study, Europe, Japan and USA <sup>330</sup>	M	40–59	12 763	Mortality (424)	25 years	Various methods in each country	Inverse, not statistically significant	
Men in Finland, Italy and the Netherlands, Part of Seven Countries Study <sup>340</sup>	M	40–59	3 108	Mortality (187)	25 years	Cross check diet history	Inverse, not statistically significant	
Nurses Health Study, USA <sup>341</sup>	F	34–59	121 700	Incidence (593)	16 years	Repeated food frequency questionnaire	Inverse, statistically significant	
Nurses and Health Professionals Follow-up studies, USA <sup>324, 325</sup>	M+F	F: 34–59 M: 40–75	F: 77 283 M: 47 778	Incidence (793)	10-12 years	131 item food frequency questionnaire at intervals	Inverse, not statistically significant	Inverse, statistically significant (carotenoids)
<div>F female M male</div>								

## **Case–control studies**

The literature review identified 32 case–control studies that satisfied the inclusion criteria. These are summarized in Table 7.2. As the case–control studies were not used in the meta-analyses, fewer study details are provided here for conciseness. These studies were conducted across a range of populations including the United States and Canada (13), Sweden (2), United Kingdom (2), Greece (1), Italy (1), Spain (1), Poland (2), India (1), China (4), Japan (2) and Brazil (1). 19 of the studies collected data from men and women, 7 from men only and 6 from women only.

Of these studies, 18 found an inverse relationship between a high intake of fruit or vegetables and lung cancer. When separate associations with fruit and vegetables were analysed there seemed to be a greater number of studies finding significant associations with vegetables as a group compared to fruit as a group. Four of the studies found significant associations only with specific types of vegetables, such as pumpkins and onions <sup>342</sup> or tomatoes <sup>343</sup> or carrots <sup>344</sup>, or in specific age groups such as men between 60–79 years of age <sup>345</sup>. The results of these subgroup analyses should be treated with caution.

Of the four case–control studies that specifically collected and analysed data on non-smokers, two found no association while two found a significant inverse association between fruit or vegetable consumption and lung cancer. Due to the inherent limitations of case–control studies, the results do not necessarily imply that dietary modification after quitting smoking is effective in reducing risk. Ex-smokers with elevated vegetable and fruit consumption could have been high consumers while they were also smokers. However, the results of case–control studies seem consistent with the results of the cohort studies.

**Table 7-2      Summary of case–control studies reporting an association between fruit and vegetable intake and lung cancer**

Study population	Sex	Association with fruit or vegetables	Association with specific risk factors only
South-West England <sup>346</sup>	M+F	Null	Inverse: carrots, tomato
Nagoya, Japan <sup>347</sup>	M+F	Inverse	--
Buffalo, NY, USA <sup>348</sup>	M+F	Inverse	--
NJ, USA <sup>349</sup>	M	Inverse	--
Lombardy, Italy <sup>344</sup>	M+F	--	Inverse: carrots
Texas, <sup>350</sup>	M	Null	--
China, Hong Kong SAR, never smokers <sup>351</sup>	F	Null	--
Louisiana, USA <sup>352</sup>	M+F	Inverse	--
Hawaii <sup>353</sup>	M+F	Inverse	--
Toronto, Canada <sup>354</sup>	M+F	Inverse (vegetables)	--
Greece, never smokers <sup>355</sup>	F	Inverse (fruits)	--
Stockholm, never smokers <sup>356</sup>	M+F	Null	--
Oxford, <sup>357</sup>	M	Null	--
Yunnan Miners, China <sup>358</sup>	M	Inverse (vegetables) Null (fruit)	--
Florida, USA, female, never smokers <sup>359</sup>	F	Inverse (vegetables) Null (fruit)	--
Tokai, Japan <sup>360</sup>	M+F	Inverse	--
New Jersey, USA <sup>361</sup>	M+F	Inverse (vegetables)	--
New York, USA <sup>362</sup>	M+F	Inverse	--
Hawaii <sup>363</sup>	M+F	Null	--
NE China, women <sup>364</sup>	F	Null	--
Yunnan, China, miners <sup>365</sup>	M	Null	--
Kerala, India <sup>342</sup>	M+F	Null	Inverse: pumpkin, onion
Rio de Janeiro, Brazil <sup>366</sup>	M+F	Null	--
West Sweden <sup>367</sup>	M	Inverse (vegetables)	--
New Jersey <sup>368</sup>	M+F	Inverse	--
Barcelona, Spain <sup>369</sup>	F	Inverse (veg) Null (fruits)	--
China <sup>370</sup>	M+F	Null	--
Poland <sup>371</sup>	M	Inverse	Null for green vegetables
USA <sup>372</sup>	M+F	Null (vegetables) Inverse (fruit)	--
Poland <sup>373</sup>	F	Inverse – no smoking adjusting	--
Europe, never smokers <sup>343</sup>	M+F	Null	Inverse for tomatoes
New York, USA <sup>345</sup>	M+F	Null (carotene)	Inverse for men only

F Female; M Male; n.a. not applicable ; - no data; Null non-significant ;

Inverse= statistically significant protective association of high versus low fruit/vegetable consumption

**Experimental studies**

Although outside the criteria of this review, it is important to repeat some of the previously noted evidence from experimental studies that may appear to contradict the protective relationship of fruit and vegetables on lung cancer. The CARET study <sup>258</sup> and the ATBC study <sup>374</sup> were randomized control trials designed to investigate the

effect of beta-carotene high-dose supplementation on lung cancer. The results of these trials suggested a harmful effect (increase in incidence and mortality) of beta-carotene supplementation in current smokers. This suggests that raised beta-carotene may be a marker associated with other protective factors found in foods <sup>240</sup> and that the status of the antioxidant hypothesis might need to be re-evaluated critically <sup>375</sup>.

## **Confounding and interactions**

All studies of lung cancer adjusted for age, sex and smoking in their analyses, except for one case–control study from Poland <sup>373</sup> which did not adjust for smoking. Other potential confounders dealt with statistically included: environmental tobacco smoke; previous lung disease; occupational exposure (arsenic, asbestos, chloromethyl ethers, and nickel); radon; air pollution; total energy intake; intake of other macronutrients; body mass index (BMI); physical activity; and socioeconomic status (using educational level or occupation used as a proxy). The extent of adjustment varied among studies.

Smoking is the most important potential confounder to consider given the strength of the association between smoking and lung cancer. There is also the possibility of smoking being an effect modifier but published results are contradictory. The studies reviewed here have dealt with smoking in a number of ways. Some studies have not only adjusted for current smoking status but have also considered the intensity of current smoking behaviour (as the number of cigarettes smoked per day), age of starting smoking and duration of smoking. For current non-smokers, several studies have also adjusted for time since quitting (including intensity) in ex-smokers. A couple of studies also adjusted for time since quitting for subjects who quit during follow-up.

An important issue, highlighted by Ziegler et al. <sup>42</sup>, is that several studies have shown that consumption of vegetables, fruits and carotenoids is higher in non-smokers compared with current smokers, and that consumption is inversely related to smoking intensity in smokers. Thus, those studies that only considered smoking status without smoking intensity might have generated inflated estimates of the protective effect of fruit and vegetables.

The interpretation of these studies is difficult given the strong misclassification bias and the strong association between lung cancer and tobacco use, making it difficult to ensure that all the confounding effects from smoking have been removed <sup>376</sup>.

## **Summary**

There is some evidence of an inverse relationship in many populations between lung cancer risk and fruit and vegetable consumption. There is currently not enough evidence to justify stratifying the results by smoking status.

## ***Stomach cancer***

The current literature review identified 12 cohort and 32 case–control studies that investigated the association between gastric cancer risk (incidence and mortality) and the consumption of fruit and/ or vegetables. Overall the evidence seems to support an inverse association between fruit and vegetable consumption and gastric cancer risk.

## **Cohort studies**

The 14 cohort studies were conducted in Western and non-Western populations including two from Japan, one from China, two from mainland USA, three of Japanese descendants in Hawaii and six from Europe. The Asian populations had a relatively high risk of stomach cancer. The results of the studies are summarized in Table 7-3.

Of these studies, nine investigated the effect of fruit and vegetable intake on gastric cancer incidence while the remaining five studied mortality. Two cohorts were investigated in more than one study (the Netherlands Cohort Study, and Japanese descendants in Hawaii in the Honolulu Heart Program). Seven cohorts consisted of both men and women, six studies investigated men only and one study focused exclusively on post-menopausal women. Follow up of cohorts ranged from 5 to 25 years. A statistically significant inverse association between gastric cancer and fruit and vegetable intake was reported in four studies. This inverse relationship was found in populations of both European and Japanese origin. The ten other studies showed inverse relationships, but they were not statistically significant for fruit and vegetable or nutrient intake.



**Table 7-3 Summary of cohort studies reporting measures of association between intake of fruit and vegetables and stomach cancer**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake	Association with diet proxy
Japanese general population survey (1965 census cohort) <sup>333, 286</sup>	M+F	40+	265 118	Mortality (5 247)	17 years	Crude—not clear	Inverse, statistically significant trend	
Rural Cohort, Japan <sup>377</sup>	M+F	N/a	9 753	Mortality (57)	6 years	Food frequency questionnaire	Inverse, not statistically significant	
Iowa Women's Health Study, USA <sup>378</sup>	F	55–69	34 691	Incidence (26)	7 years	127 item food frequency questionnaire	Inverse, not statistically significant	
Men of German and Scandinavian origin, USA <sup>379</sup>	M	N/a	17 633	Mortality	20 years	Food frequency questionnaire	Inverse, not statistically significant	
The Netherlands Cohort Study <sup>380, 381</sup>	M+F	55–69	120 852	Incidence (282)	6.3 years	150 item food frequency questionnaire	Inverse, statistically significant	Non-significant trends: inverse (vitamin C), Positive (beta-carotene, retinol)
The Caerphilly Study, Wales <sup>382</sup>	M	45–69	2 112	Mortality (45)	13.8 years	Food frequency questionnaire	Inverse, not statistically significant	
Seven Country Study; Europe, Japan and USA <sup>383</sup>	M	40–59	12 763	Mortality (n/a)	25 years	Various methods (population intake)	Inverse, not statistically significant	
Cohort of Swedish Twins <sup>384</sup>	M+F	N/a	11 546	Incidence (116)	21 years	Crude food frequency questionnaire	Inverse, statistically significant	
Smokers in ATBC study, Finland <sup>338</sup>	M	50–69	27 110	Incidence (111)	6.1 years	Food frequency questionnaire		Inverse, not statistically significant (flavanoids)
Japanese residents, random survey of Hawaiian households <sup>385</sup>	M+F	18+	11 907	Incidence (108)	14.8 years	Food frequency questionnaire	Inverse, statistically significant	
Cohort of Hawaiian men of Japanese Ancestry, Honolulu Heart Program <sup>386</sup>	M	49–68	7 990	Incidence (150)	19 years	Food frequency questionnaire	Inverse, not statistically significant	
Cohort of Hawaiian men of Japanese Ancestry, Honolulu Heart Program (case cohort study) <sup>387</sup>	M	49–68	8 006	Incidence (111)	18 years	Food frequency questionnaire and 24-hour recall	Inverse, not statistically significant	
Linxian Nutrition Intervention Trial Cohort, China <sup>388</sup>	M+F	N/a	29 584	Incidence (539)	5 years	Dietary interview	Inverse, not statistically significant (fruits)	

### **Case–control studies**

The 32 case–control studies, summarized in Table 7.4, represented a wider range of populations and geographical areas than the cohort studies. Studies were conducted in the United States and Canada (5), northern and southern Europe (14), Japan (4), China (3), Turkey (2), Poland, Korea, Mexico and Venezuela (1 each). All but two of these studies were carried out on both men and women. Not all the populations were at high risk of stomach cancer.

Of the 32 studies, 20 reported a significant inverse association between total fruit or vegetable consumption and gastric cancer risk. A further nine studies found an inverse association only with specific food types or within a sub-cohort. Particular attention was placed on the consumption of allium vegetables (onions, leeks, garlic, chives). One study (from Venezuela) found that the risk of gastric cancer incidence was inversely related (protective effect) with vegetable intake but directly related (harmful effect) with fruit intake. This is the only study reporting a significant positive (harmful) relationship <sup>389</sup>. Despite the inherent limitations created by recall bias in case–control studies, the evidence is strong and consistent with a protective effect of a diet high in fruit and vegetables, and supports the findings of the cohort studies.

**Table 7-4      Summary of case-control studies reporting a measure of association between intake of fruit and vegetables and gastric cancer**

Study population	Sex	Association with fruit and vegetables	Association with specific risk factors only
Louisiana, USA <sup>390</sup>	M+F	Null (vegetables), Inverse (fruits)	--
Canada <sup>391</sup>	M+F	Null	Inverse for citrus fruit
Greece <sup>392</sup>	M+F	Inverse (veg), Null (fruits)	--
Japan <sup>393</sup>	M+F	Null	Inverse for spinach/onions
Cracow, Poland <sup>394</sup>	M+F	Null (vegetables) Inverse (fruit)	--
Milan, Italy <sup>395</sup>	M+F	Inverse	--
China <sup>396</sup>	M+F	Null	Inverse for spinach
Japan <sup>397</sup>	M+F	Null	Inverse for mandarins
NE China <sup>398</sup>	M+F	Inverse	--
Italy <sup>399</sup>	M+F	Inverse	Null for cooked vegetables
United Kingdom <sup>400</sup>	M+F	Inverse	--
USA <sup>401</sup>	M+F	Inverse	--
Turkey <sup>402</sup>	M+F	Inverse	--
Los Angeles, USA <sup>364</sup>	M	Null	--
Germany <sup>403</sup>	M+F	Inverse (fruit)	--
Poland <sup>404</sup>	M+F	Inverse	--
Japan <sup>405</sup>	M+F	Null	Inverse for raw veg. in men
Spain <sup>406</sup>	M+F	Inverse	Inverse (flavenoids)
Spain <sup>407</sup>	M+F	Inverse	Null for raw vegetables
Japan <sup>408</sup>	M+F	Null	Inverse for raw vegetables
Turkey <sup>409</sup>	M+F	Null	--
Belgium <sup>410</sup>	M+F	Inverse	--
Barcelona, Spain <sup>411</sup>	M+F	Inverse	--
Sweden <sup>412</sup>	M+F	Inverse	--
France <sup>413</sup>	M+F	Null	--
Korea <sup>414</sup>	M+F	Null	Inverse for spinach
USA <sup>415</sup>	M+F	Inverse	Inverse only for fruits
Sweden <sup>7</sup>	M+F	Inverse for vegetables, null for fruits	
Shanghai, China <sup>416</sup>	M+F	Inverse	Null—vegetables in women
Mexico City, Mexico <sup>417</sup>	M+F	Inverse	
Venezuela <sup>389</sup>	M+F	Inverse vegetables	Positive for fruit
Italy <sup>418</sup>	M+F	Null	Inverse for citrus fruit

F female; M male; n.a. not applicable; - no data; Null association=not significant;

Inverse= statistically significant protective association of high versus low fruit/vegetable consumption

## Confounding

Most studies appear to have made appropriate adjustments for potential confounding factors. All adjusted for age and sex, and most studies adjusted for smoking and alcohol consumption. Other factors, considered particularly in prospective studies, were previous history of stomach illness, family history of stomach cancer, other dietary components, and socioeconomic status. Protective associations remained even after adjustment for other dietary factors such as salty foods or starchy foods in some studies 391 395 400 411 412 414 .

*Helicobacter Pylori* infection plays a major role in the aetiology of gastric cancer yet few studies were able to collect this information given the retrospective nature of many studies and the fact that it is only relatively recently that it has been possible to test for infection. As noted earlier, dietary antioxidants may act by inhibiting the inflammatory response mounted by the body to *Helicobacter* infection<sup>419</sup>. Similarly, no studies were able to take account of individual's interleukin 1b genotype, which again modulates the body's response to *Helicobacter*<sup>420</sup>.

## Summary

There is an inverse relationship between fruit and vegetable intake and gastric cancer risk in both cohort and case-control studies in different populations worldwide. The relationship remains after adjustment for confounding. Some of the variations in the findings from separate studies could be due to between-country differences in the varieties of fruit and vegetables consumed, the methods of consumption (raw or cooked), the number of specific fruit or vegetable items included in the questionnaires used, or the validity of the dietary assessment methods.

Although *Helicobacter Pylori* infection is an established risk factor, its relationship with fruit and vegetable consumption remains inadequately understood. As noted previously, a multistage model of gastric carcinogenesis is now accepted, according to which different dietary and non-dietary factors, involving genetic susceptibility, are involved at different stages in the cancer process. However, while a protective effect of supplementation of vitamin C and beta-carotene in the progression of pre-malignant gastric lesions was found in Latin America <sup>254</sup>, but alpha-tocopherol and beta-carotene supplement trials in Finland showed no effect. Furthermore, as noted above, genetic

factors may also play a role. In spite of this, results from the observational studies suggest a protective effect of diets rich in fruit and vegetables.

## ***Colorectal cancer***

The systematic review identified 15 cohort studies and 35 case–control studies that examined the association between colorectal cancer risk (both incidence and mortality) and the consumption of fruit and vegetables. Details of these studies are given in Table 7-5 and Table 7-6. Overall the evidence support an inverse relationship between fruit and vegetable intake and colorectal cancer risk (incidence and mortality), although it is not as strong as that for gastric cancer.

The studies investigating colorectal cancer also included a number of studies that looked separately at colonic and rectal cancers. For the purposes of this review the results of all these outcomes have been combined.

## **Cohort studies**

The cohort studies were conducted on a limited range of populations, with most studies being from the United States (10), the others being from Europe (3) and Japan (1). It should be noted that three of the study cohorts were common to more than one study.

The majority of studies used cancer incidence as the outcome, with mortality being used in only four studies. Eight studies investigated both men and women, while three investigated men only and four looked at women only.

Although a number of the studies reported a protective effect of fruit and vegetable consumption on colorectal cancer risk, only three of the 15 showed a statistically significant inverse trend. This is summarized in Table 7-5. A further eight studies did show some inverse association between vegetable consumption and colorectal cancer risk for certain sub-group analyses with vegetables, fruits, or colon or rectal cancer separately; three studies a statistically insignificant positive association between fruit and vegetable intake and colorectal cancer.



**Table 7-5 Summary of cohort studies reporting a measure of association between intake of fruit and vegetables and colorectal cancer**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake	Association with diet proxy
Japanese general population survey (1965 census cohort) <sup>333 286</sup>	M+F	40+	265 118	Mortality: colon (552), rectum (563)	17 years	Crude- not clear	Inverse (colon), positive (rectum), not statistically significant	
The Adventist Health Study, USA <sup>421</sup>	M+F	16+	25 493	Mortality (182)	21 years	Food frequency questionnaire	Inverse (rectum), positive (colon), not statistically significant	
Iowa Women's Health Study, USA <sup>422</sup>	F	55-69	34 691	Incidence (212)	5 years	127 item food frequency questionnaire	Inverse, not statistically significant	
Leisure World Cohort, California <sup>326</sup>	M+F	Elderly	11 580	Incidence (202)	9 years	Food frequency questionnaire	Inverse, not statistically significant (women)	
Leisure World Cohort, California <sup>423</sup>	M+F	Elderly	10 473	Incidence (110)	6 years	Food frequency questionnaire		No association (beta-carotene)
The Netherlands Cohort Study <sup>424</sup>	M+F	55-69	120 852	Incidence (910)	6.3 years	150 item food frequency questionnaire	Inverse, not statistically significant	Non-significant trends: inverse (vitamin C), Positive (beta-carotene, retinol)



**Table 7-5 (continued) Summary of cohort studies reporting a measure of association between intake of fruit and vegetables and colorectal cancer**

Study population(s)	Sex	Age range	Study size	No of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake	Association with diet proxy
Mammography study Cohort, Sweden <sup>264</sup>	F	N/a	61 463	Incidence (460)	9.6 years	Food frequency questionnaire	Inverse, statistically significant	
Male smokers in ATBC study, Finland <sup>425</sup>	M	50–69	27 111	Incidence (185)	8 years	Food frequency questionnaire	Positive, not statistically significant	
American Cancer Society Prevention Study, USA and Puerto Rico <sup>426</sup>	M+F	30+	764 343	Mortality—colon (1 150)	6 years	32 item food frequency questionnaire	Inverse, statistically significant	
Cohort of Hawaiian men of Japanese Ancestry, Honolulu Heart Program <sup>427</sup>	M	49–68	8 006	Incidence: colon (102), rectum (60)	18 years	Food frequency questionnaire		Inverse, statistically significant (vitamin C)
New York University Women's Health Study, USA <sup>428</sup>	F	34–65	14 727	Incidence (100)	7.1 years	Food frequency questionnaire	Positive, not statistically significant	
Nurses Health Study, USA <sup>429</sup>	F	34–59	88 757	Incidence (787)	16 years	Repeated food frequency questionnaire		Inverse, not statistically significant (fibre)
Health Professional Follow-up study <sup>430</sup>	M	40–75	47 949	Incidence (205)	6 years	Repeated food frequency questionnaire	Inverse (fruits), Positive (vegetables), not statistically significant	
Nurses and Health Professionals Follow-up study <sup>431, 272</sup>	F M	30–55 40–75	47 325 88 764	Incidence: colon (937), rectum (244)	10–16 years	Repeated food frequency questionnaire	Positive, not statistically significant	

### **Case–control studies**

The reference populations in case–control studies came from a wider range of countries than those in the cohort studies. They included studies from France, Italy, Belgium, Switzerland, Spain, China, Singapore, Japan, Australia, Argentina, Uruguay, the Russian Federation, Canada and the United States. All studies collected data on both men and women. It should be noted that two of the population cohorts (Australia and New York) were each common to two studies.

Results from 21 out of the 33 populations showed an inverse association with vegetables or fruits while three found an inverse association only with specific food types (tomatoes; or spinach, onion and pumpkin; or tomatoes, peppers and celery). This is summarized in Table 7.7.

It should be noted that although the majority of colorectal cancers are adenocarcinomas, some studies found differences depending on tumour location (proximal vs distal colon vs rectum). This suggests that pooling of results from different anatomical sites and cell types in many of the cohort and case–control studies may have obscured a true relationship for subgroups. However, at present there is insufficient evidence to identify any differences in risk between sub-groups.



**Table 7-6      Summary of case-control studies reporting a measure of association between intake of fruit and vegetables and colorectal cancer**

Study population	Sex	Association with fruit or vegetables	Association with specific risk factors
Japan <sup>393</sup>	M+F	Null	Inverse with spinach/ onion/ pumpkin
France <sup>432</sup>	M+F	Inverse	--
Australia <sup>433; 434</sup>	M+F	Inverse (V)	--
Western NY, USA <sup>435; 436</sup>	M+F	Null	Inverse for tomatoes/ peppers/ celery
Italy <sup>395</sup>	M+F	Inverse (V)	--
Utah, USA <sup>437</sup>	M+F	Inverse (F)	Inverse: cruciferous vegetables
Belgium <sup>438</sup>	M+F	Inverse (F)	--
Wisconsin, USA <sup>439</sup>	M+F		Inverse: cruciferous vegetables
Singapore <sup>440</sup>	F+M	Null	--
Utah, USA <sup>441</sup>	F+M	Null (F), inverse (M)	--
Spain <sup>442</sup>	M+F	Null	--
China <sup>443</sup>	M+F	Inverse (V)	--
Argentina <sup>444</sup>	M+F	Inverse (V)	--
California, USA <sup>445</sup>	M+F	Null	--
Australia <sup>446</sup>	M+F	Null	--
Italy <sup>447</sup>	M+F	Null	Inverse for spinach
Russian Federation <sup>448</sup>	M+F	Null	Positive for dried fruits
Italy <sup>449</sup>	M+F	Inverse	Tomatoes
Japan <sup>450</sup>	M+F	Null	--
The Netherlands <sup>451</sup>	M+F	Inverse (V)	--
Uruguay <sup>452</sup>	M+F	Inverse (F+V)	--
USA <sup>453</sup>	M+F	Null (M), inverse (F)	--
France <sup>454</sup>	M+F	Null	--
Italy <sup>455</sup>	M+F	Inverse	--
Hawaii <sup>456</sup>	M+F	Inverse	--
USA Kaiser <sup>457</sup>	M+F	M: Inverse (V) F: Null	--
French Canadians <sup>458</sup>	M+F	Inverse (V)	--
Italy <sup>459</sup>	M+F	Inverse	--
NYU, USA <sup>460</sup>	M+F		Inverse (folate)
Switzerland <sup>461</sup>	M+F	Inverse	--
Washington State, USA <sup>462</sup>	M+F	Inverse(F), null(M)	--
Italy	M+F	Inverse (V)	--
Italy <sup>463</sup>	M+F	Inverse	--

F      female                      M      male

n.a.    not applicable

Null    association not statistically significant;

Inverse=statistically significant protective association of high versus low fruit/vegetable consumption.

**Confounding and interaction**

All studies adjusted for the effect of sex and age. Other confounders taken into account in the statistical analyses included total energy, meat, fat and protein intakes, body mass index, smoking, alcohol consumption, physical activity, family history, dietary

supplements, education, and area of residence. By analogy with the evidence on lung and stomach cancer, it is conceivable that an effect might only be anticipated in those with particular genotypes (e.g. fast acetylators) who also consume significant quantities of meat. These individuals are at increased risk of colon cancer as potentially carcinogenic metabolites of meat are preferentially excreted in the bile rather than in the urine<sup>201</sup>. Many studies have excluded cases with strong family history of colorectal cancer or with conditions such as familial polyposis coli, and inflammatory bowel diseases such as ulcerative colitis or Crohn's disease from the final analyses.

## **Summary**

On their own, the prospective epidemiological studies have yet to produce conclusive evidence to support an association between colorectal cancer and fruit and vegetable intake. However, the hypothesis is still worthy of further consideration, as there appears to be an inverse relationship in many cohort studies and in two-thirds of the case-control studies in a wide range of different populations. The relationships remained after adjustment for measurable confounding.

The uncertainty in the studies of colorectal cancer is unsurprising in view of the complex biological mechanisms involved in its aetiology, and the fact that there are different sub-types. The incidence can be expected to reflect a complex combination of genetic factors (including factors that affect the colonic mucosa and those that determine whether certain toxins are excreted in bile or urine), diet (both carcinogenic and protective factors), and hormonal status.

## ***Oesophageal cancer***

This systematic review identified four cohort and 28 case-control studies investigating the association of fruit and vegetable intake with oesophageal cancer risk (incidence and mortality). Most studies looked at oesophageal cancer mortality or at the effect of fruit and vegetable consumption on incidence and mortality considered jointly. In this review, these outcomes have been considered together, assuming that, since oesophageal cancer survival rates are very poor, incidence is closely correlated with mortality.

## **Cohort studies**

The four cohort studies are from China (2), Japan and Norway. Details of the studies are given in 7-7. Both Chinese studies were based on the same population in the

Linxian province, which has one of the highest incidence rates of oesophageal cancer in the world. The study population is part of a large nutrition intervention trial.

Three of the studies showed a statistically non-significant inverse trend with fruit and vegetable intake. One Chinese study found an inverse relationship with fresh vegetable consumption <sup>464</sup>, while the other found an inverse relationship between the intake of both fruit and vegetables and oesophageal cancer incidence <sup>388</sup>. The most recent study of Norwegian men also found a non-significant inverse relationship between fruit and vegetable intake and oesophageal cancer incidence, but this was based on only 22 cancer events.

**Table 7-7      Summary of cohort studies reporting a measure of association between n intake of fruit and vegetables and oesophageal cancer**

Study population(s)	Sex	Age range	Study size	No. of cases	Follow-up	Exposure measure	Association with fruit or vegetable intake
Japanese general population survey (1965 census cohort) <sup>333, 286</sup>	M+F	40+	265 118	Mortality (585)	17 years	Crude—not clear	Positive, not statistically significant
Cohort of Norwegian Men <sup>465</sup>	M	35–74	10 960	Incidence (22)	25 years	32 item food frequency questionnaire	Inverse, not statistically significant
Linxian Nutrition Intervention Trial Cohort, China <sup>464</sup>	M+F	40–69	12 693	Incidence and mortality (1 162)	15 years	Structured questionnaire interview	Inverse, not statistically significant
Linxian Nutrition Intervention Trial Cohort, China <sup>388</sup>	M+F	40–69	29 584	Incidence (640)	5.25 years	Structured questionnaire interview	Inverse, not statistically significant

## **Case–control studies**

Case–control studies provide the majority of evidence for the association of fruit and vegetable consumption and oesophageal cancer risk. The 28 case–control studies identified are summarized in Table 7-8.

The studies came from a wide range of populations worldwide: this includes China (4), Japan (2), China, Hong Kong SAR (2), India (2), South America (3), United States (4) and Europe (10). Most of these studies investigated populations of men and women, but five investigated only men and two studied only women. Not all of the study populations were from populations at a high risk of oesophageal cancer.

Of the 28 studies, 20 reported significant inverse associations between oesophageal cancer and fruit and/ or vegetable consumption. Interestingly, more of these inverse associations were with fruit rather than vegetables.

Although many studies did not specifically look at the histological type of oesophageal cancer, the majority of the results presented here are likely to be limited to squamous cell cancer. There was one study, in women from the United Kingdom <sup>466</sup>, which focused on oesophageal adenocarcinoma. This study found an inverse association of cancer risk with a higher consumption of fruit but not vegetables.

**Table 7-8      Summary of case-control studies reporting a measure of association between intake of fruit and vegetables and oesophageal cancer**

Study population	Sex	Association with fruit and vegetables group (or proxy)	Association with specific risk factors only
South America (5 countries) <sup>467</sup>	M+F	Inverse	--
Brazil <sup>468</sup>	M+F	Inverse (fruit)	--
Uruguay <sup>469</sup>	M+F	Null	--
USA, <sup>470</sup>	M	Inverse	Squamous cell carcinoma only
USA <sup>471</sup>	M+F	Inverse	--
California, USA <sup>472</sup>	M+F	Inverse	--
South Carolina, USA <sup>473</sup>	M	Inverse (fruit), null (vegetables)	--
Linxian, China <sup>474</sup>	M+F	Null	--
Shanxi, China <sup>475</sup>	M+F	Null	Inverse for cabbage
Shanghai, China <sup>476</sup>	M+F	Inverse (fruit), null (vegetables)	--
Heilongjiang, China <sup>477</sup>	M+F	Null	--
Japan <sup>478</sup>	M	Null	--
Japan <sup>479</sup>	M	Inverse	--
China, Hong Kong SAR <sup>480</sup>	M+F	Inverse	--
China, Hong Kong SAR, never smokers/drinkers <sup>481</sup>	M+F	Inverse	--
India <sup>482</sup>	M+F	Null	--
India <sup>483</sup>	M+F	Inverse (vegetables), null (fruit)	--
Italy, non-smokers <sup>484</sup>	M+F	Inverse	--
Milan, Italy <sup>485</sup>	M+F	Inverse	--
Italy <sup>486</sup>	M+F	Inverse (fruit), null (vegetables)	--
Milan, Italy <sup>487</sup>	F	Inverse (fresh fruit), null (green vegetables)	--
Northern Italy <sup>488</sup>	M+F	Inverse	Null for cooked vegetables
Italy <sup>489</sup>	M+F	Null	Inverse for fruits in smokers
Athens, Greece <sup>490</sup>	M+F	Null	Inverse for vegetables in adenocarcinoma type
Switzerland <sup>491</sup>	M+F	Inverse	--
France, multicentre <sup>492</sup>	M	Inverse	--
France <sup>493</sup>	M+F	Inverse	--
England, Scotland <sup>466</sup>	F	Null (vegetables), inverse (fruit)	-- Adenocarcinoma only

F      female; M      male  
n.a.    not applicable  
Null    association not statistically significant  
Inverse statistically significant protective association

**Confounding**

Most studies adjusted for age and sex. Other potential confounders considered in several studies included smoking, total energy intake, pickled vegetable intake, body mass index, marital status, occupational status, educational or socioeconomic status, and ethnicity. Supplement intake, such as vitamins, and intake of hot teas, were also

considered in a few studies. However, as the aetiology is not well understood it is unclear whether all potentially important confounders were considered.

## **Summary**

The epidemiology of oesophageal cancer shows wide geographical variation in incidence and mortality rates. Striking differences have been reported not only between sub-regions of the world and countries, but also within smaller geographical areas <sup>494</sup>. Oesophageal cancer risk also varies with ethnicity and sex. Changes in incidence observed in migrant studies appear to indicate that environmental factors, including potentially diet, play an important role in the aetiology of oesophageal cancer.

The main risk factors for oesophageal cancer in Europe were previously thought to be tobacco smoking and alcohol consumption. However, between 1950 and 1985, mortality from oesophageal cancer in 17 European countries either decreased or increased only slightly <sup>495</sup>. This trend differed from that of lung cancer and tobacco smoking, and cirrhosis and alcohol consumption, which share risk factors and have increased substantially during the same period. The results suggest that other population-wide changes in protective risk factors, such as improvements in diet after World War II, had mitigated against the effect of tobacco and alcohol and resulted in a reduction of oesophageal cancer risk. In China, which has a very high incidence of oesophageal cancer, an ecological study in 65 counties showed that oesophageal cancer mortality was significantly associated with fruit consumption, but no correlation was observed with tobacco smoking or alcohol consumption <sup>496</sup>. There is also strong evidence from other ecological studies that dietary factors, especially fruit and vegetable consumption, may affect rates of oesophageal cancer <sup>494</sup>.

This review of the literature showed that there are few prospective observational studies of the effect of fruit and vegetable consumption on oesophageal cancer, and that most of these show non-significant inverse associations. Evidence from supplement intervention trials is also inconclusive. Two randomized supplement intervention trials in Linxian, China, tested the effect of nutrient/vitamin supplementation in a population with very high rates of oesophageal cancer <sup>262</sup>. Modest protective effects were seen for mortality in the supplemented group in both trials, but none of the results was statistically significant for oesophageal or gastric cancer. In spite of this, evidence from case-control studies appears to support an inverse relationship between fruit and vegetable consumption and oesophageal cancer risk (incidence and mortality) although

this is not as strong as that for stomach cancer. In view of this it was decided to include oesophageal cancer in the GBD study.

### ***Estimation of relative risks for cancer outcomes***

This section describes, for each selected outcome, the studies that were chosen based on the selection criteria for meta-analysis outlined, and the final estimates of relative risks derived

#### **Lung cancer**

Four studies met our selection criteria for meta-analysis. These are shown in Table 7-9.

#### **Data transformation**

Relative risks in the Nurses Health and Health Professionals Follow-up study (NHS/HPFS) and the Finnish Mobile Clinic Health examination study were available with fruit and vegetable intake treated as a continuous variable. The NHS/ HPFS gave the relative risk in terms of one additional serving per day, which were converted as 80 g/day. The authors of the Finnish Mobile Clinic Study provided relative risks per 1 g/day which were transformed on a log scale to give estimates expressed as an 80 g/day increase (as discussed earlier—see chapter 6).

For the Netherlands Cohort Study and the National Health Interview Study data had been analysed as quintiles and quartiles of intake respectively. The method of Greenland and Longnecker <sup>269</sup> was used to estimate the weighted regression slope over the published relative risks. This gave estimates of relative risks as a continuous variable.



**Table 7-9      Relative risk estimates for the association between lung cancer and fruit and vegetable consumption considered for the CRA project**

Study Population		Sex (age)	Outcome	RR (95% CI) per 80 g/day increase in fruit and vegetable intake
The Netherlands Cohort Study <sup>331</sup>		M+F (55–69)	Incidence	0.89 (0.83–0.96)
National Health Interview Study, USA <sup>332</sup>		M+F (fruit)	Mortality	0.9 (0.69–1.17)
Nurses Health and Health Professionals Follow-up study, USA <sup>324</sup>		M+F (34–75)	Incidence	0.99(0.91–1.08)
Finland Mobile Clinic Health Examination Study <sup>327</sup>		M+F (55–69)	Incidence	0.92 (0.85–0.99)
F	female	M	male	

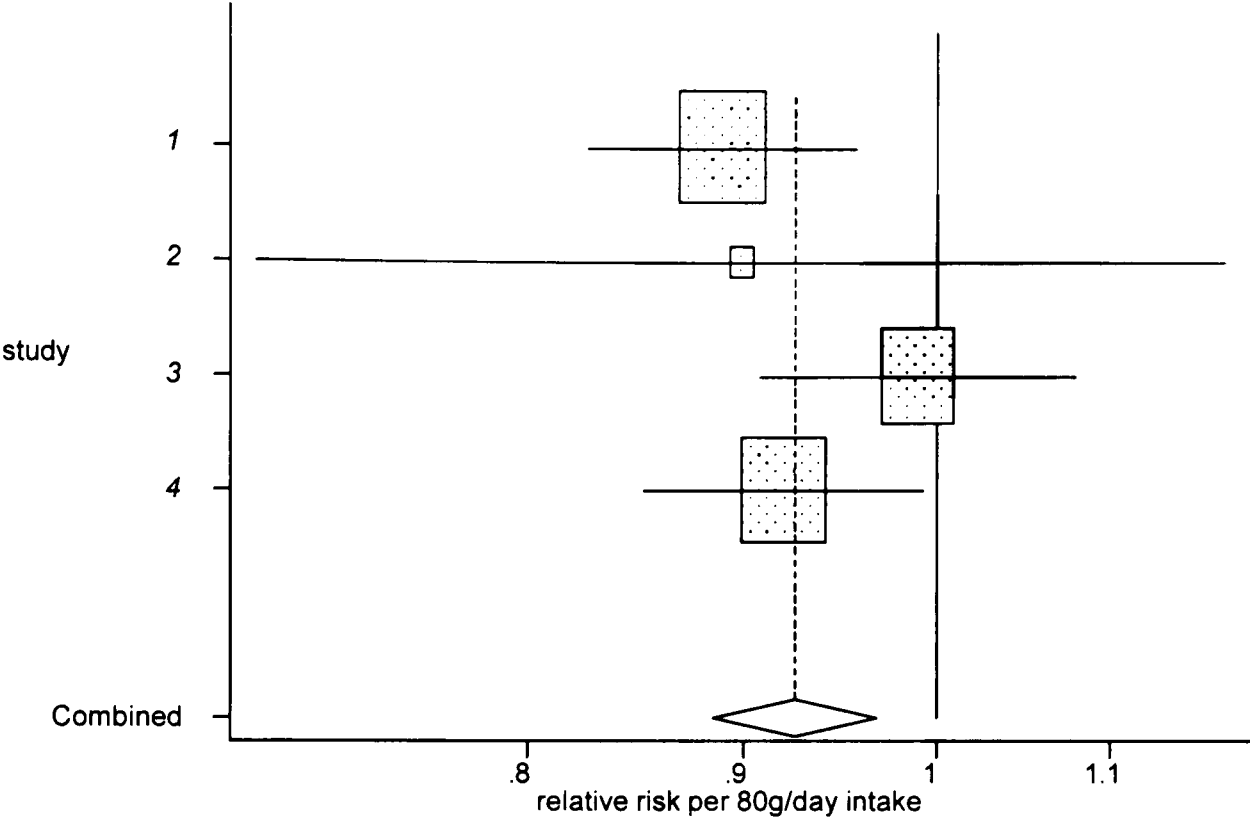
**Meta-analysis**

As there was no evidence of heterogeneity (chi-squared value of 3.553, df= 3, P = 0.314), the results from fixed effect meta-analysis were used (estimates were very similar to those obtained with the random effects methods). The pooled relative risk estimate was 0.926 (0.886–0.968) for an 80 g/day increase in fruit and vegetable consumption. The forest plot of the results is shown in Figure 7-1.

These results are consistent with those found in the only other pooled analysis for lung cancer-fruit and vegetable association<sup>497</sup>. In this study they found strong, inverse associations in the age-adjusted analyses, and analyses adjusted for education, body mass index, alcohol intake, and energy intake for total fruit, total vegetable, and total fruit and vegetable intakes. Associations were similar among never, past, and current smokers.

Smith-Warner et al. estimated that the pooled results for total fruit and vegetable intake gave a slightly lower reduction in lung cancer risk than the meta-analysis results for this project. Due to the potential for residual confounding in this analysis it was decided to use the more conservative estimate of pooled relative risk which is equivalent to 0.96 (0.93–0.99) per 80 g/ day increase in fruit and vegetable intake<sup>497</sup>. However, one should note that because of the limitations in the accuracy with which fruit and vegetable exposure was specified, any effect might be underestimated.

**Figure 7-1** Fixed effects meta-analysis of the association of fruit and vegetable intake with lung cancer



Key to studies  
1 = The Netherlands Cohort study, 2 = National Health Interview Study, 3 = NHS/HPFS, 4 = Finland Mobile Clinic Health Examination Study

**Gastric cancer**

Only one study, the Netherlands Cohort Study on Diet and Cancer, met the selection criteria for meta-analysis. This is shown in Table 7-10.

The relative risks obtained from the Netherlands Cohort Study are consistent with the effect estimates obtained from most case-control studies reviewed, but they are more conservative than the estimates of the meta-analysis from Norat et al.<sup>267</sup>.

**Table 7-10     Relative risk estimate for the association between gastric cancer and fruit and vegetable consumption considered for the CRA project**

Study Population	Sex (age)	Outcome	RR (95% CI) per 80 g/day increase in fruit and vegetable intake	
The Netherlands Cohort Study <sup>380</sup>	M+F (55–69)	Incidence	0.94	(0.86–1.03)

**Data transformation**

Data from the Netherlands Cohort Study had been analysed as quintiles of intake of fruit and vegetables. The method of Greenland and Longnecker <sup>269</sup> was used to estimate the weighted regression slope over the published relative risks to estimate relative risks as a continuous variable for an 80 g/day increase in total fruit and vegetable consumption. This gave a final relative risk estimate for gastric cancer incidence and mortality for the CRA project of 0.94 (0.86-1.03) for an 80 g/day increase in fruit and vegetable consumption.

**Colorectal cancer**

Three studies met our selection criteria for meta-analysis. These are shown in 7-11.

**Table 7-11     Relative risk estimates for the association between colorectal cancer and fruit and vegetable consumption considered for the CRA project**

Study Population	Sex (age)	Outcome	RR (95% CI) per 80 g/day Increase in fruit and vegetable intake	
The Netherlands Cohort Study <sup>424</sup>	M (55–69)	Incidence	Colon 1.00	(0.92–1.09)
			Rectal 0.93	(0.86–1.02)
	F (55–69)	Incidence	Colon 0.99	(0.9–1.09)
			Rectum 1.01	0.89–1.14)
Swedish Mammography Study <sup>264</sup>	F	Incidence	Colorectal 0.93	(0.87–0.995)
Nurses Health and Health Professionals Follow-up study, USA <sup>272</sup>	M+F (34–75)	Incidence	Colon 1.02	(0.98–1.05)
			Rectal 1.02	(0.95–1.09)

**Data transformation**

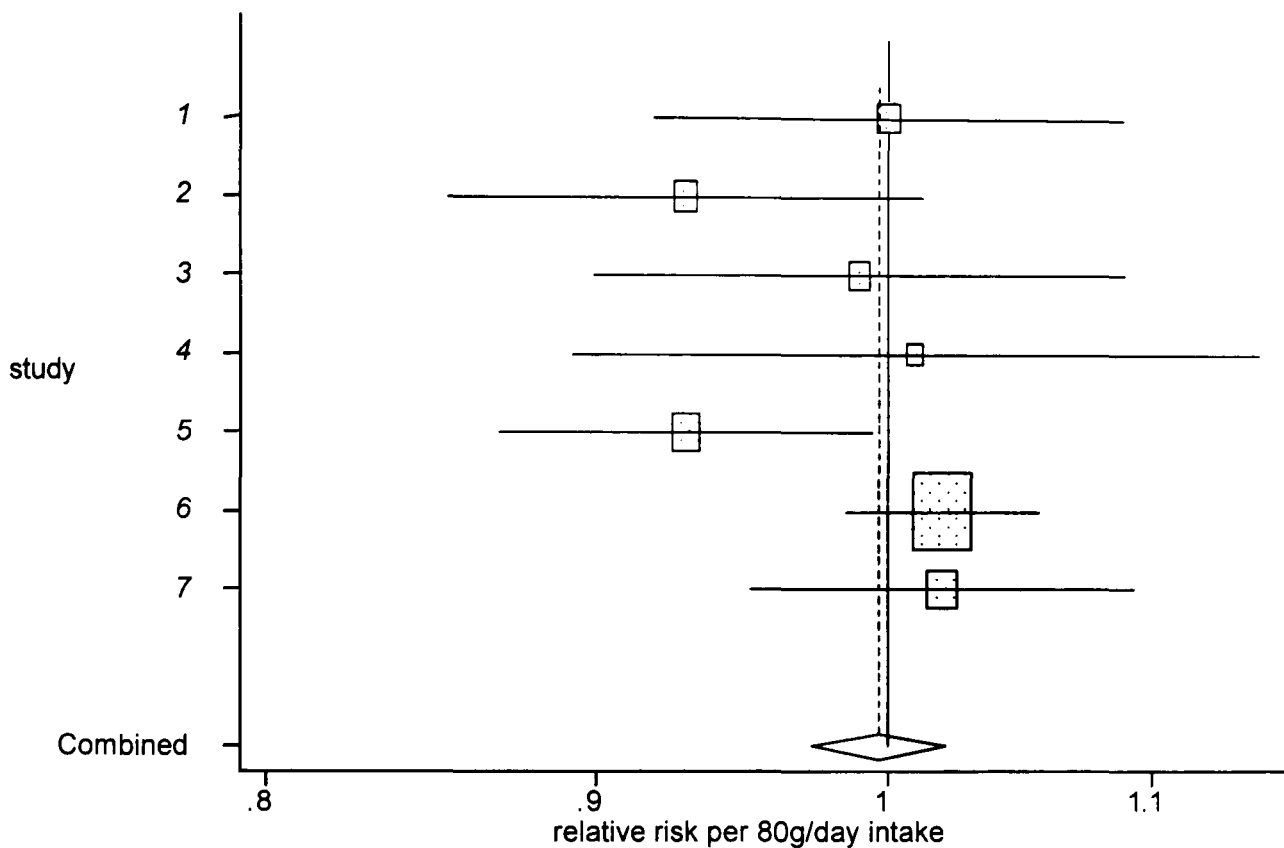
Relative risk in the Nurses Health and Health Professionals Follow-up study (NHS/HPFS) was available with fruit and vegetable intake treated as a continuous variable. The NHS/ HPFS gave the relative risk in terms of one additional serving per day, which was converted as 80 g/day.

For the Netherlands Cohort Study and the Swedish Mammography Study, data had been analysed as quintiles and quartiles of intake respectively. The method of Greenland and Longnecker <sup>269</sup> was used to estimate the weighted regression slope over the published relative risks to give relative risks as a continuous variable.

### **Meta-analysis**

The NHS/HPFS and the Netherlands Cohort study had presented results separately for colon and rectal cancers. The Netherlands Cohort study had also analysed data for men and women separately. These subgroup analyses were combined in the meta-analysis as if they were separate studies. The test for heterogeneity gave a chi-squared value of 8.849 (df= 6; P = 0.182). As there was no evidence of heterogeneity the fixed effects results were used (these were very similar to the results obtained with the random effects method). The pooled relative risk estimate was 0.997 (0.973–1.021) for an 80 g/day increase in fruit and vegetable consumption. The results are shown in Figure 7.2.

**Figure 7-2      Fixed effects meta-analysis of the association of fruit and vegetable intake with colorectal cancer**



Key to studies  
 1 = The Netherlands Cohort study (men, colon cancer); 2 =The Netherlands Cohort study (women, colon cancer); 3 = The Netherlands Cohort study (men, rectal cancer); 4 =The Netherlands Cohort study (women, rectal cancer); 5 = Swedish Mammography Study (colorectal cancer); 6 = NHS/HPFS (men and women, colon cancer); 7 =NHS/HPFS (men and women, rectal cancer)

**Interpretation of the effect estimate**

The Swedish Mammography Study indicated that the inverse association was stronger, and the dose–response more evident, among individuals who consumed the lowest amounts of fruit and vegetables. In a sub-group analysis of the population in the lowest quartile of fruit and vegetable intake, the relative risk was 0.77 (0.67–0.97) for an increase of one serving per day <sup>264</sup>. It may be that individuals who consume very low amounts of fruit and vegetables have the greatest risk of colorectal cancer. This is consistent with the presence of a plateau effect and highlights the need to study populations with a wide range of dietary exposures. This finding was not replicated in the NHS/ HPFS <sup>272</sup>, although it should be noted that this study had a high reference exposure category and might not have been able to examine very low intake of fruit and vegetables as in the Swedish study.

**Oesophageal cancer**

None of the cohort studies of oesophageal cancer in the systematic review met our selection criteria. Studies were either of high-risk populations, had a small number of events, had a relatively short follow-up time, or did not cover total fruit and vegetable intake. Very few of the case-control studies had calculated risk for total fruit and vegetable consumption, and none had estimated relative risks for quantified levels of fruit and vegetable consumption that would allow estimation of a continuous variable. Thus, it was decided to use the results of the meta-analysis from Norat et al.<sup>267</sup> to derive the final relative risk estimates. This meta-analysis calculated risk estimates for fruit and vegetables separately per 100 g/day intake. The pooled relative risks associated with an increase of consumption of 80 g/day were calculated. These are, 0.828 (0.708–0.960) for fruit, and 0.935 (0.878–1.008) for vegetables. The results suggested risk reductions of between 17.2% and 6.5% per 80 gram/day increase in fruit intake and vegetable intake respectively. In this, the most conservative relative risks were used (i.e. those for vegetables only, 0.935 (0.878–1.008)).

***Summary of the estimates of relative risks***

The relative risk estimates for cancer outcomes, and their 95% confidence intervals are summarized in Table 7-12. Estimates are expressed as the change in relative risk associated with an 80g increase in daily fruit and vegetable intake.

As discussed earlier, the relative risks are applied to all sub-regions and to both males and females. Assuming age attenuation at the extremes of age, these relative risks apply for individuals aged 15–69 years. For older adults the relative risks were reduced by a quarter for ages 70–79, and by half for over 80 years of age. Under the age of 15 years a relative risk of one was applied.

**Table 7-12 Relative risks with increased fruit and vegetable consumption (95% confidence intervals) by age group**

Outcome	Age group (years)							
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+
Lung cancer	1.00	1.00	0.96 (0.93-0.99)	0.96 (0.93-0.99)	0.96 (0.93-0.99)	0.96 (0.93-0.99)	0.97 (0.91-1.02)	0.98 (0.92-1.03)
Gastric cancer	1.00	1.00	0.94 (0.86-1.03)	0.94 (0.86-1.03)	0.94 (0.86-1.03)	0.94 (0.86-1.03)	0.95 (0.87-1.04)	0.97 (0.89-1.06)
Colorectal cancer	1.00	1.00	0.99 (0.97-1.02)	0.99 (0.97-1.02)	0.99 (0.97-1.02)	0.99 (0.97-1.02)	0.99 (0.97-1.02)	1.00 (0.97-1.02)
Oesophageal cancer	1.00	1.00	0.94 (0.88-1.01)	0.94 (0.88-1.01)	0.94 (0.88-1.01)	0.94 (0.88-1.01)	0.95 (0.89-1.02)	0.97 (0.91-1.04)

Unit of change in risk: change per 80 g/day increase in fruit and vegetable intake

This chapter and the preceding one have presented the results of the systematic reviews and methods used for estimating the relationship between fruit and vegetable consumption and the six selected disease outcomes.

The relative risk estimates presented here are subject to the limitations imposed by the methods used, which have been designed to allow assessment of a wide range of diverse exposures across a variety of disciplines as part of the Global Burden of Disease Study. Such quantitative assessment is inevitably subject to considerable uncertainty surrounding the estimation of exposure–outcome relationships which has been discussed in chapter 5. How these results have been used to estimate the burden of disease due to low fruit and vegetable consumption is discussed in chapter 8.



## **Chapter 8 Estimating burden of disease due to low fruit and vegetable consumption: globally and nationally**

The Global Burden of Disease project estimates the burden of disease attributable to a risk factors using the Comparative Risk Assessment method (CRA) <sup>145 146</sup>. Three sources of information are combined to derive the burden of disease attributable to low fruit and vegetable intake; first information on the level and distribution of consumption in the population (chapter 3) and a baseline level of intake that would yield the lowest overall population risk; second, estimates of the association between fruit and vegetable intake and selected health outcomes (chapters 5, 6 and 7); third current estimates of mortality and morbidity of the diseases studied. This chapter will describe the methods used to estimate the burden of disease globally using these information sources, to present the results that emerged from this process, and then show how the methods were applied to the national context in the Republic of Slovenia.

### ***Estimating attributable burden for the theoretical minimum risk distribution***

The CRA approach involved estimating the population attributable fraction (PAF). The PAF is defined as the proportional reduction in population disease or mortality that would occur if exposure to a risk factor, such as fruit and vegetable intake, were reduced to an alternative (counterfactual) distribution <sup>146</sup>. Hence, the attributable burden of disease, defined by the generalised potential impact fraction (PIF) equation in figure 8.1, is the difference between the currently observed burden and the burden that would be observed if the distribution of exposure was at a level that would result in the lowest theoretical population risk, referred to as the theoretical minimum risk distribution <sup>145</sup>. Within the GBD programme, DALYs are used as the measure of the burden of disease in populations, on the basis that they are viewed as a valid summary indicator of population health (Chapter 2) <sup>93</sup>.

Fruit and vegetable intake is unusual in that there is an inverse-risk relationship, i.e. it is the potential protective effect of fruits and vegetables that is considered. Hence, the theoretical minimum risk involves selecting a plausible maximum consumption level at which the protective effect is maximised. There is a further complication in that, for an effect to be protective, it implies that it is protective against something else. The protective effect will therefore be a function of both the level of exposure to fruit and vegetables and to the factor against which it is protecting. It is not, however, possible to

take this into account in the current GBD methodology so. for the present purposes, this caveat will simply be noted.

Notwithstanding this issue, while there is clear evidence that increased fruit and vegetable consumption reduces disease risk, the levels of intake that would give the greatest protection remain unknown. Consequently the theoretical minimum risk level was chosen on the basis of knowledge of the highest achievable levels of current fruit and vegetable intake worldwide. Evidence of an association between fruit and vegetable intake and diseases comes mainly from studies performed in Europe and North America. Thus, the counterfactual was selected based on the ranges of intakes observed in these populations (the maximum being between 500 and 550 g/day). The theoretical maximum consumption was set at 600 g/day in adults. Due to the uncertainty of the evidence related to variation of effect with age, gender and region (chapters 6 and 7), the same threshold was assumed to apply equally to all selected health outcomes, and to all adult populations of both genders worldwide.

**Figure 8-1 Potential impact fraction equation used to estimate the population attributable fraction for low intake of fruit and vegetables**

$$PIF = \frac{\int_{x=0}^m RR(x)P(x) - \int_{x=0}^m RR(x)P'(x)}{\int_{x=0}^m RR(x)P(x)}$$

- Where
- $RR(x)$  =relative risk at exposure level x.
- $P(x)$  = population distribution of exposure.
- $P'(x)$  =counterfactual distribution of exposure.
- $m$  =maximum exposure level.

**Mortality and DALY estimates for estimating attributable burden**  
 Estimation of the Global Burden of Disease required estimates of mortality, YLD, YLL and DALYs for the six diseases of interest in all WHO world regions for the year 2000. As collecting these data was beyond the scope of the thesis, the relevant figures were obtained from the WHO. The WHO have estimated the required inputs for the Global

Burden of Disease 2000 study <sup>498</sup> as published in the World Health Report 2002 <sup>144</sup>. The WHO's figures for mortality are based on analysis of routinely collected data in countries with valid systems of vital registration. Elsewhere they are estimated using certain modelling techniques and thus there is a need for some circumspection when interpreting them. Slovenia does, however, have a vital registration system of high quality.

YLD estimates are largely derived from models that use data on levels of disability associated with certain diseases in the few countries where this is available, adjusted for a variety of putative determining factors. These have been estimated for each sub-region and country <sup>498</sup>. The GBD 2000 uses the latest population estimates for WHO Member States prepared by the UN Population Division <sup>499</sup>. The data have been used to develop internally consistent estimates of mortality, incidence, prevalence, duration and DALYs for over 130 major causes, for each WHO Member State. The work leading to these tables was undertaken by the WHO Global Programme on Evidence for Health Policy in collaboration with WHO technical programmes and with scientists worldwide. Documentation and GBD 2000 summary tables are available on the WHO website (<http://www.who.int/publications/cra/en/>).

The WHO DALY estimates were used to calculate the attributable burden for each disease. An Excel-based workbook was prepared with the help of Dr S. Van Der Hoorn (WHO, Geneva and University of Auckland) to enable the attributable burden to be estimated globally and for each WHO sub-region. These worksheets linked the WHO DALY estimates for diseases, with the prevalence and relative risk estimates for fruit and vegetables estimated as described in chapters 3, 6 and 7.

### **Global Burden of Disease due to low fruit and vegetable consumption in the year 2000: results**

I have presented the detailed estimates in a standard set of six tables for each disease (Appendices A-F), as well as for all causes combined (Table 8-1). The complete list of diseases and injuries used for the Global Burden of Disease (GBD) study, and which are therefore the "target" list of outcomes to quantify the disease/injury burden for each risk factor, can be found at <http://www.who.int/publications/cra/en/>.

For each risk factor-disease pair, the statistics are shown by age, sex and 14 epidemiological sub-regions (required by the CRA). The eight GBD age-groups have

been used: 0–4, 5–14, 15–29, 30–44, 45–59, 60–69, 70–79 and ≥80 years. The countries comprising each sub-region are shown in Table 3-1. The classification is an attempt to subdivide the various WHO regions into subcategories of countries with more or less similar epidemiological characteristics as assessed by the comparative magnitude of, and the relationship between, child (0–4 years) and adult (15–59 years) mortality. Five broad epidemiological characteristics have been defined, not all of which are present in any one WHO region: A. Very low child mortality and very low adult mortality; B. Low child mortality and low adult mortality; C. Low child mortality and high adult mortality; D. High child mortality and high adult mortality; and E. High child mortality and very high adult mortality. These mortality strata were then applied to the six main WHO regions (African Region, Region of the Americas, Eastern Mediterranean Region, European Region, South-East Asia Region, and Western Pacific Region). The results in Table 8-1 report the results according to these mortality strata.

The definitions of what are “very low”, “low”, “high” and “very high”, while arguably somewhat arbitrary and context dependent, are meant to distinguish between countries where the epidemiological transition has essentially been completed (e.g. western Europe, Japan, USA) and those where it has not (e.g. Latin America, China), specifically identifying countries where major health reversals affecting adults have occurred, either because of marked increases in vascular and respiratory diseases and injuries (eastern Europe), or because of HIV/AIDS (southern and eastern Africa).

The first three sub-tables for all causes combined (Table 8-1) and for each of the six disease outcomes (appendices A-F) present the detail on the population attributable fraction (PAF). The estimated risk-factor–disease PAF by age, sex and sub-region are shown for mortality (table *a*), years of life lost to premature mortality (YLL) (table *b*) and overall disease burden as measured by disability-adjusted life years (DALYs) (table *c*). The definition and formulation of YLL and DALYs are described elsewhere<sup>93</sup>. In brief, YLL measure the consequences of the age-pattern of mortality caused by a risk factor, with YLL being greater for those risk factors causing death at younger ages (e.g. childhood and maternal underweight) compared to those leading to mortality at older ages (e.g. elevated blood pressure). DALYs are a measure of the total disease burden caused by a given exposure, either through causing premature mortality (YLL) or through non-fatal outcomes that result from exposure (e.g. long-term consequences of non-fatal injuries attributable to alcohol).

The second set of three tables per disease gives the total number of deaths (table *d*), YLL (table *e*) and DALYs (table *f*) due to low fruit and vegetable intake in 2000, by age, sex and sub-region. These estimates are obtained by applying the respective population attributable fractions in tables *a–c* to the estimated total number of deaths, YLL and DALYs for each regional population, estimated as part of the broader GBD 2000 project <sup>498</sup>. As such, the tables show the total (absolute) population health effects of low fruit and vegetable intake, measured in terms of deaths, years of life lost (premature deaths) or overall disease burden.

The results show that increasing individual fruit and vegetable consumption up to the theoretical maximum intake could reduce the overall worldwide burden of disease for ischaemic heart disease and ischaemic stroke by about 31% (30% in males and 31% for females) and 19% (18% in males and 19% in females) respectively. For stomach and oesophageal cancer the potential reduction in disease attributable to an increase in fruit and vegetable intake was 19% and 20% respectively. Attributable risk fractions were lower for lung and colorectal cancer (12% and 2%). The total worldwide mortality attributable to inadequate fruit and vegetable consumption is estimated to be 2.635 million deaths. This is equivalent to a loss of 25.8 million DALYs per year.

As Figure 8.2 shows, these figures mean that low fruit and vegetable consumption is among the top 12 of the risk factors considered by the WHO in terms of global disease burden <sup>63</sup>. It is a significant determinant, particularly of cardiovascular diseases, in both developed and developing regions, although its impact is greater in developed regions. For example, in the European region, low fruit and vegetable intake is accountable for 4.3% and 3.4% of the total attributable disease burden in men and women respectively.

It is, however, also important to note that other aspects of nutrition emerged as important in the overall Global Burden of Disease; about 15% of global disease is estimated to be due to the effects of undernutrition and micro-nutrient deficiencies, and a similar amount of disease can be attributed to other risk factors that have significant dietary components <sup>63</sup>. In Europe, dietary-associated factors (blood pressure, alcohol intake, serum cholesterol, overweight, low fruit and vegetable intake) comprise five of the top seven risk factors.

With respect to the six diseases considered in this work, diet is only one of many contributory factors (with others being, for example, smoking or lack of physical

activity), and even the dietary component may vary in different circumstances. Clearly attempts need to be made to tease out these relationships. The CRA project has begun by estimating the joint population attributable fraction for some major worldwide diseases <sup>500</sup>. For example, for ischaemic heart disease, it estimates that low fruit and vegetable intake contributes 33% in high mortality developing regions, 31% in lower mortality developing regions and 28% in developed regions to the total population attributable risk.

**Table 8-1      The global disease burden due to low consumption of fruits and vegetables (all causes) by age, gender and sub-region**

**8.2a: Attributable fraction of mortality (%)**

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	2	5	4	5	3	5	2	4	1	2	1
AFR-E	NA	NA	NA	NA	0	0	1	0	2	4	5	6	4	6	3	5	1	1	1
AMR-A	NA	NA	NA	NA	0	1	4	3	9	6	10	8	7	7	5	5	7	6	6
AMR-B	NA	NA	NA	NA	1	1	3	3	8	7	11	9	8	7	5	5	6	5	5
AMR-D	NA	NA	NA	NA	1	1	1	1	4	4	5	5	5	5	3	4	2	3	3
EMR-B	NA	NA	NA	NA	1	1	6	4	12	8	11	9	8	8	5	6	7	5	6
EMR-D	NA	NA	NA	NA	1	1	3	2	7	7	7	8	6	7	4	4	3	3	3
EUR-A	NA	NA	NA	NA	0	1	3	2	7	3	7	5	5	5	3	3	5	4	4
EUR-B	NA	NA	NA	NA	1	1	5	4	9	7	11	11	9	9	7	7	8	7	8
EUR-C	NA	NA	NA	NA	1	1	5	5	12	10	17	18	16	17	12	14	12	14	13
SEAR-B	NA	NA	NA	NA	1	1	2	2	6	5	8	8	7	7	5	5	4	5	5
SEAR-D	NA	NA	NA	NA	1	2	3	3	10	8	13	13	9	9	7	6	6	5	6
WPR-A	NA	NA	NA	NA	1	1	3	3	6	3	6	4	5	4	3	3	4	4	4
WPR-B	NA	NA	NA	NA	1	1	3	3	6	5	8	7	6	6	4	4	5	5	5
World	NA	NA	NA	NA	1	1	2	2	7	6	10	10	8	8	5	6	5	5	5

## 8.2b Attributable fraction of YLL (%)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	2	4	4	5	3	5	2	4	0	1	0
AFR-E	NA	NA	NA	NA	0	0	1	0	2	3	5	6	4	6	3	5	0	1	0
AMR-A	NA	NA	NA	NA	0	1	4	3	9	6	10	8	7	7	5	5	6	5	6
AMR-B	NA	NA	NA	NA	1	1	3	3	8	7	11	9	8	7	5	5	3	3	3
AMR-D	NA	NA	NA	NA	1	1	1	1	4	4	5	5	5	5	3	4	1	1	1
EMR-B	NA	NA	NA	NA	1	1	6	4	11	8	11	9	8	8	5	6	4	3	4
EMR-D	NA	NA	NA	NA	1	1	3	2	7	7	7	8	6	7	4	4	1	1	1
EUR-A	NA	NA	NA	NA	0	1	3	2	6	3	6	5	5	5	3	3	5	3	4
EUR-B	NA	NA	NA	NA	1	1	5	4	9	7	11	11	9	9	7	7	6	5	5
EUR-C	NA	NA	NA	NA	1	1	5	4	12	10	17	18	16	17	12	14	9	12	10
SEAR-B	NA	NA	NA	NA	1	1	2	2	6	5	8	8	7	7	5	5	3	3	3
SEAR-D	NA	NA	NA	NA	1	2	3	3	9	8	13	13	9	9	7	6	3	3	3
WPR-A	NA	NA	NA	NA	1	1	3	3	5	3	6	4	5	4	3	3	4	3	4
WPR-B	NA	NA	NA	NA	1	1	3	3	6	5	8	7	6	6	4	4	3	3	3
World	NA	NA	NA	NA	1	1	2	2	7	6	10	10	8	8	5	6	3	2	3



### 8.2c Attributable fraction of DALYs (%)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	2	3	3	4	3	4	2	3	0	1	0
AFR-E	NA	NA	NA	NA	0	0	1	0	2	3	4	4	3	5	2	4	0	0	0
AMR-A	NA	NA	NA	NA	0	0	2	1	6	3	8	5	5	5	4	4	3	2	3
AMR-B	NA	NA	NA	NA	0	0	2	1	5	4	8	6	6	5	4	4	2	2	2
AMR-D	NA	NA	NA	NA	0	0	1	1	2	3	4	4	4	4	3	3	1	1	1
EMR-B	NA	NA	NA	NA	1	0	3	2	7	4	8	6	7	7	4	4	3	2	2
EMR-D	NA	NA	NA	NA	1	0	2	1	4	4	6	6	5	6	3	3	1	1	1
EUR-A	NA	NA	NA	NA	0	0	1	1	4	1	5	2	4	3	3	3	3	2	2
EUR-B	NA	NA	NA	NA	0	0	3	1	6	4	9	8	8	7	6	6	4	3	3
EUR-C	NA	NA	NA	NA	1	0	4	2	10	6	15	13	13	14	10	12	7	7	7
SEAR-B	NA	NA	NA	NA	1	0	2	1	4	3	6	6	6	6	4	5	2	2	2
SEAR-D	NA	NA	NA	NA	0	1	2	2	7	5	11	10	8	8	6	6	2	2	2
WPR-A	NA	NA	NA	NA	0	0	2	1	4	2	4	3	4	3	3	2	3	2	2
WPR-B	NA	NA	NA	NA	0	0	1	1	4	3	6	6	6	5	4	4	2	2	2
World	NA	NA	NA	NA	0	0	2	1	5	4	8	7	6	6	4	5	2	2	2

## 8.2d Attributable mortality (000s)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	1	1	2	1	5	7	6	8	6	9	2	4	21	31	52
AFR-E	NA	NA	NA	NA	1	1	4	2	9	9	10	10	7	12	2	6	33	41	74
AMR-A	NA	NA	NA	NA	0	0	3	1	18	7	22	12	26	21	22	38	92	79	171
AMR-B	NA	NA	NA	NA	1	0	5	2	20	10	24	15	21	16	10	14	81	58	139
AMR-D	NA	NA	NA	NA	0	0	0	0	1	1	2	2	2	2	1	2	7	7	14
EMR-B	NA	NA	NA	NA	0	0	2	1	8	3	8	4	6	5	2	3	27	15	43
EMR-D	NA	NA	NA	NA	1	1	4	2	14	11	15	15	12	15	5	5	51	48	98
EUR-A	NA	NA	NA	NA	0	0	2	1	15	4	24	9	32	24	21	38	95	75	169
EUR-B	NA	NA	NA	NA	0	0	4	1	15	6	26	16	24	24	10	19	80	67	147
EUR-C	NA	NA	NA	NA	1	0	13	3	52	17	81	51	64	91	23	84	234	247	481
SEAR-B	NA	NA	NA	NA	1	1	4	2	12	9	18	15	15	14	5	7	55	48	103
SEAR-D	NA	NA	NA	NA	3	7	17	13	99	55	130	106	97	94	32	35	378	311	689
WPR-A	NA	NA	NA	NA	0	0	1	0	4	1	7	2	8	5	6	10	26	19	45
WPR-B	NA	NA	NA	NA	2	1	12	7	51	28	86	55	85	81	33	59	269	232	501
World	NA	NA	NA	NA	12	14	73	39	325	169	459	320	405	413	174	323	1449	1277	2726

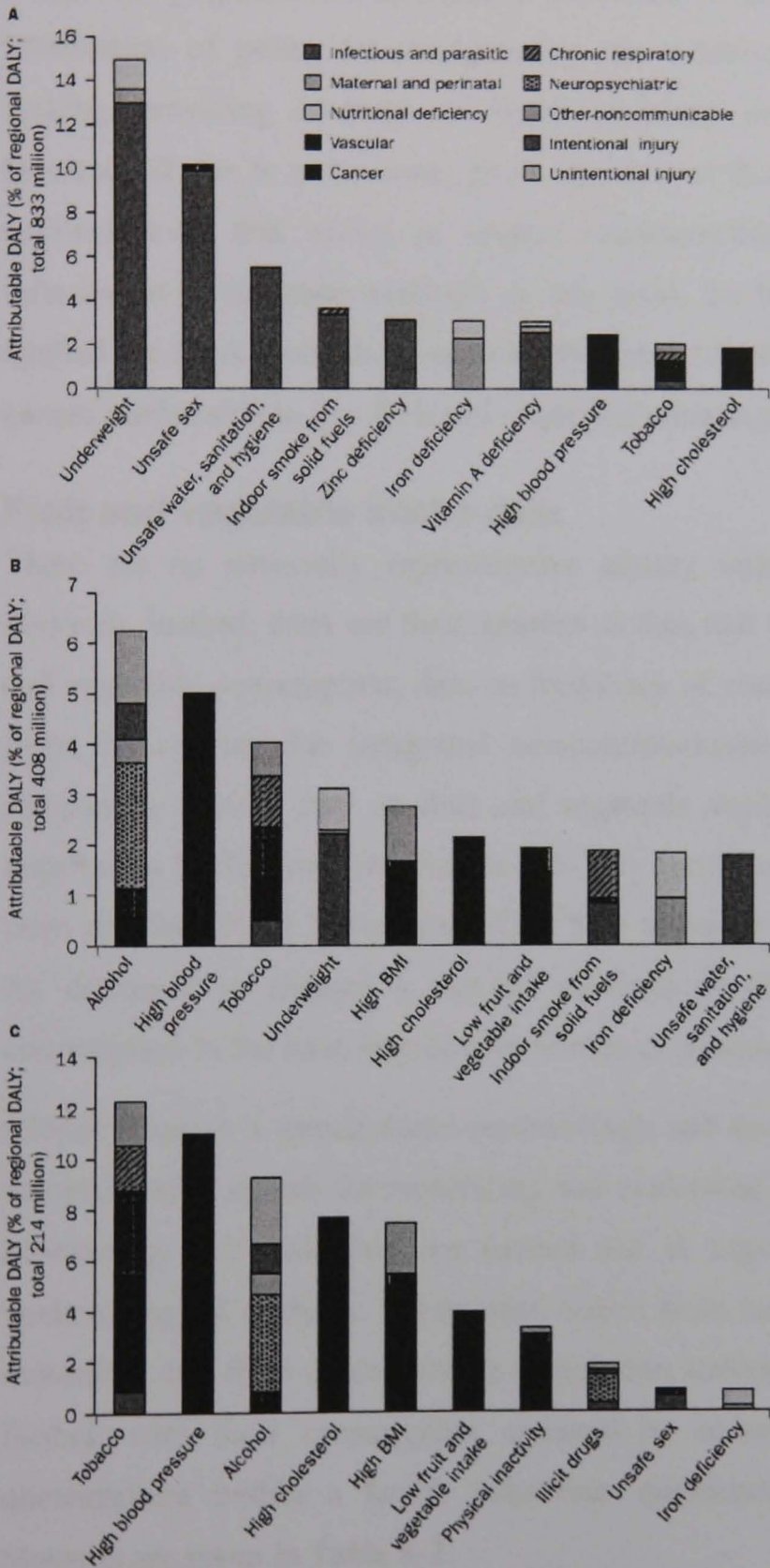
## 8.2e Attributable YLL (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	16	21	41	35	78	114	56	75	27	51	5	10	223	307	530
AFR-E	NA	NA	NA	NA	35	36	88	47	136	143	88	101	36	65	5	16	388	407	795
AMR-A	NA	NA	NA	NA	6	3	80	34	272	113	197	117	126	111	41	63	721	440	1161
AMR-B	NA	NA	NA	NA	25	14	117	56	298	158	216	142	103	89	21	28	780	487	1267
AMR-D	NA	NA	NA	NA	6	5	10	7	21	19	17	15	10	10	2	3	66	60	126
EMR-B	NA	NA	NA	NA	13	8	54	22	128	51	67	36	30	26	5	6	299	149	448
EMR-D	NA	NA	NA	NA	38	30	95	54	215	164	133	140	58	82	10	12	548	481	1030
EUR-A	NA	NA	NA	NA	5	2	57	17	225	55	212	85	154	124	39	66	692	350	1042
EUR-B	NA	NA	NA	NA	13	8	90	33	232	88	232	156	118	130	20	37	705	453	1158
EUR-C	NA	NA	NA	NA	34	9	298	73	799	265	732	493	328	501	44	166	2236	1507	3743
SEAR-B	NA	NA	NA	NA	38	22	90	58	180	134	157	144	73	80	12	17	549	455	1003
SEAR-D	NA	NA	NA	NA	105	246	407	327	1482	854	1156	1015	477	531	70	82	3699	3054	6752
WPR-A	NA	NA	NA	NA	2	1	16	7	66	21	59	23	41	26	12	16	196	94	290
WPR-B	NA	NA	NA	NA	72	43	280	181	765	452	758	523	415	443	73	127	2363	1770	4133
World	NA	NA	NA	NA	409	450	1725	951	4897	2630	4079	3065	1995	2270	359	648	13463	10014	23477

## 8.2 f Attributable DALYs (000s)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	20	25	48	43	89	136	62	85	28	54	5	11	253	354	607
AFR-E	NA	NA	NA	NA	41	42	100	58	154	171	96	115	38	69	6	16	434	471	905
AMR-A	NA	NA	NA	NA	9	6	101	51	318	145	223	139	138	127	43	68	833	536	1368
AMR-B	NA	NA	NA	NA	31	19	141	73	349	198	242	164	111	97	22	29	896	581	1476
AMR-D	NA	NA	NA	NA	6	5	11	9	23	22	18	17	11	11	2	3	72	67	140
EMR-B	NA	NA	NA	NA	14	9	59	25	137	60	73	43	32	29	5	6	322	172	494
EMR-D	NA	NA	NA	NA	44	34	109	66	236	193	146	158	62	87	10	12	607	550	1157
EUR-A	NA	NA	NA	NA	9	8	72	24	256	67	238	102	168	142	41	71	785	413	1198
EUR-B	NA	NA	NA	NA	15	10	104	42	258	105	254	176	124	139	21	39	777	511	1288
EUR-C	NA	NA	NA	NA	38	11	330	89	875	314	796	560	345	536	46	173	2431	1684	4115
SEAR-B	NA	NA	NA	NA	45	25	105	71	204	160	172	164	77	86	12	18	614	524	1139
SEAR-D	NA	NA	NA	NA	128	267	488	408	1657	1028	1287	1165	506	566	73	86	4139	3521	7660
WPR-A	NA	NA	NA	NA	5	3	22	10	81	26	69	29	46	31	13	18	237	118	354
WPR-B	NA	NA	NA	NA	84	51	333	219	901	548	870	608	453	481	78	134	2718	2042	4761
World	NA	NA	NA	NA	489	516	2024	1187	5541	3175	4546	3525	2140	2455	378	686	15117	11544	26662

**Figure 8-2** Burden of disease due to leading regional risk factors divided by disease type in high-mortality developing regions (A), lower-mortality developing regions (B), and developed regions (C)



Source Ezzati et al 2002 <sup>63</sup>

## ***Estimating the burden of disease due to fruit and vegetable intake in Slovenia***

It has been proposed that information on burden of disease can be used to enhance the formulation of policy by strengthening the evidence base that underlies decision-making, providing evidence on health problems and possibilities for intervention. However, if this is to be done, given that it is at the national, or in some cases sub-national level that policy is usually implemented, it will be necessary for the information to be made available at this level. To begin this process in Slovenia, I applied the CRA methods to estimate the current burden of cardiovascular disease and cancer attributable to low fruit and vegetable consumption in that country.

### **Fruit and vegetable intake data**

There are no nationally representative dietary intake surveys in the Republic of Slovenia. Instead, there are three sources of data that can provide an indication of fruit and vegetable consumption; data on frequency of consumption of fruit and vegetables from the countrywide integrated non-communicable diseases intervention (CINDI) programme (2001), data on fruit and vegetable availability on the Slovenian market (equivalent to that supplied for the FAO to construct food balance sheets), and data from the Data Food Networking (DAFNE) initiative from household budget surveys. As discussed in chapter 3, not all methods provide data on fruit and vegetable consumption in the form required for burden of disease studies.

CINDI employs a standardized methodology and the programme has implemented a comprehensive system for monitoring and evaluating its programme at national levels. Monitoring and evaluation are carried out at regular intervals using standardised epidemiological methods. Information comes from routine statistics (such as those on mortality) and from representative population surveys on health behaviour and risk factors, with food consumption assessed by means of a simple food frequency questionnaire within a health behaviour questionnaire<sup>501</sup>. The available data for Slovenia are given in Table 8-2.

**Table 8-2     Fruit and vegetable intake in Slovenian Adults (source CINDI questionnaire, WHO 2002)**

	Frequency of consumption	Males (%)	Females (%)	Total (%)
Fruit intake	Once a day	24.3	29	26.9
	More than once a day	20.5	38.1	30.1
Vegetable intake	Once a day	44.8	47.9	46.5
	More than once a day	18.2	25.1	21.9

DAFNE is a research collaboration among European countries that seeks to compare each population’s food habits and monitor trends in food availability through the creation of a regularly-updated food databank using information collected within household budget surveys (HBS). By recording data on the values and quantities of household food purchases they can depict the dietary patterns prevailing in representative population samples. The results for Slovenia are given in Table 8-3.

**Table 8-3     Fruit and vegetable availability for Slovenian Adults (source DAFNE Household Budget Survey 2003)**

	Purchased (g/ person/ day)	Produced at home (g/ person/ day)	Total (g/ person/ day)
Fruit	147	50	197
Vegetables	163	118	281
Fruit and vegetables			478

I finally decided to use FAO availability data from food balance sheets. The mean population availability from food balance sheets is 539 g per person per day. This estimate is similar to that obtained from the DAFNE house hold budget surveys which estimate mean availability as 478g per person per day (Table 8-3). Data from food balance sheets was selected because the DAFNE data does not include food eaten away

from the home, and thus may underestimate fruit and vegetable consumption. The FAO data was then used to calculate national population-weighted average fruit and vegetable availability in grams per person per day. The methods for calculating FAO-derived proxy intakes are described in chapter 3. FAO data on fruit and vegetable availability in 2000 were used. Due to known wastage and losses of available food, a 33.3% adjustment figure <sup>18</sup> was used to correct the food balance sheet figures for availability to reflect fruit and vegetable consumption. Population data from the United Nations Population Division database for 2000 were used<sup>502</sup>. It should be noted (as discussed in chapter 3) that this approach may overestimate consumption. In a recent (but not nationally representative) dietary survey in Slovenia average fruit and vegetable consumption was estimated at only 304g per person per day <sup>503</sup>. This compares with an estimated intake of 359 g per person per day from Slovenian food availability statistics (Table 8-4).

Estimated consumption by age and sex is shown in Table 8-4. As discussed before (chapter 5) it is assumed that people over 80 years of age consume no more than those between 70-79 years, so the same value of consumption is used for both age groups. Given the absence of survey data from Slovenia, the standard deviations of mean intake applied were from Italian National Intake Survey data; this was considered appropriate as it is a neighbouring country that is believed to have a similar pattern of fruit and vegetable consumption.



**Table 8-4      Calculations leading to the estimation of the mean proxy intakes of vegetables and fruits in Slovenia (g/person.day)**

Sex and age groups	FAO availability estimates		Total country intake (kg/day) Adjusted <sup>b</sup>	Country Pop. Size <sup>c</sup> ('000)	Proportion of total country intake for each age-sex category <sup>d</sup> (%)	Final mean proxy intake <sup>e</sup> (g/person.day)
	(g/caput.day)					
	Crude	Adjusted <sup>a</sup>				
Males						
0-4 years				47	1.5	227
5-14 years				115	4.2	260
15-29 years				222	10.1	324
30-44 years				230	12.0	373
45-59 years				201	10.6	377
60-69 years				92	5.6	435
70-79 years				48	3.7	550
80+ years				(12)	(1.2)	550
Females						
0-4 years				44	1.4	227
5-14 years				109	4.0	262
15-29 years				212	9.8	330
30-44 years				228	11.8	370
45-59 years				198	10.7	386
60-69 years				110	6.0	389
70-79 years				88	5.0	406
80+ years				(33)	(2.5)	406
TOTAL	539	359	714051	1989	100	

a FAO mean availability adjusted for 33.3% estimated losses

b (FAO per capita intake(a) /1000) \* population size

c From United Nations Population Division. World Population Prospects: The 2002 Revision. Population Database. Available at <http://esa.un.org/unpp/copyright.html> (visited 2 October 2004)

d EU regional intake for the age-sex category /Total regional intake (Estimated from survey data obtained from 11 of the 25 EU countries - see Chapter 3 for studies used)

e FAO proxy intake in grams/person/ day = [FAO total availability for Slovenia (b)/100]\* Proportion of the total regional intake for the age-sex category (d)/ Population size for the age-sex category (c)

**DALY estimates**

The Burden of Disease estimates for Slovenia (mortality, YLL, YLD and DALYs) for the six conditions being studied (coronary heart disease, ischaemic stroke, colon cancer, oesophageal cancer, stomach cancer and lung cancer) were prepared by WHO (see above). These estimates should be interpreted with caution as, in the absence of actual data on levels of disability within the Slovenian population; they are derived from modelling techniques with extrapolation from other countries. An overview of these data, showing the leading causes of mortality, disability and burden of disease (DALYs) in Slovenia in the year 2000 is given in Table 8-5.

**Table 8-5      Leading causes of mortality, disability and burden of disease, Slovenia 2000**

Mortality (deaths)

Rank	Disease or injury	% total deaths
1	Ischaemic heart disease	16.0
2	Cerebrovascular disease	11.8
3	Trachea, bronchus and lung cancers	5.4
4	Inflammatory heart diseases	4.9
5	Lower respiratory infections	4.3
6	Colon and rectum cancers	3.7
7	Cirrhosis of the liver	3.7
8	Chronic obstructive pulmonary disease	3.6
9	Self-inflicted injuries	3.3
10	Stomach cancer	2.4

Mortality (YLL)

Rank	Disease or injury	% total YLL
1	Ischaemic heart disease	11.7
2	Cerebrovascular disease	7.9
3	Self-inflicted injuries	7.7
4	Trachea, bronchus and lung cancers	6.3
5	Cirrhosis of the liver	6.0
6	Road traffic accidents	4.8
7	Colon and rectum cancers	3.6
8	Inflammatory heart diseases	3.1
9	Breast cancer	3.0
10	Lower respiratory infections	2.7

Disease burden (DALYs)

Rank	Disease or injury	% total DALYs
1	Unipolar depressive disorders	9.3
2	Cerebrovascular disease	6.3
3	Ischaemic heart disease	6.2
4	Alcohol use disorders	4.2
5	Self-inflicted injuries	3.9
6	Chronic obstructive pulmonary disease	3.9
7	Cirrhosis of the liver	3.6
8	Trachea, bronchus and lung cancers	3.1
9	Hearing loss, adult onset	3.0
10	Road traffic accidents	3.0

Disability (YLD)

Rank	Disease or injury	% total YLD
1	Unipolar depressive disorders	18.0
2	Alcohol use disorders	7.2
3	Hearing loss, adult onset	5.8
4	Chronic obstructive pulmonary disease	5.3
5	Cerebrovascular disease	4.9
6	Alzheimer and other dementias	4.5
7	Osteoarthritis	3.7
8	Migraine	2.6
9	Bipolar affective disorder	2.2
10	Schizophrenia	2.1

**Attributable burden**

For the reasons set out previously in this chapter, the theoretical minimum risk was set at 600g/per person per day. The attributable burden of the consumption of fruit and vegetables in Slovenia in the year 2000 was estimated by using an Excel-based worksheets which linked the WHO DALY estimates for diseases, with the prevalence and relative risk estimates for fruit and vegetables estimated (as described in chapters 6 and 7). The results are given in Table 8-6.

The total mortality currently attributable to inadequate consumption of fruit and vegetables is estimated to be up to 750 deaths per year. Increasing individual fruit and vegetable consumption to up to 600 g per day (the baseline of choice) could reduce the total burden of disease by 2%, and reduce the burden of ischaemic heart disease and ischaemic stroke by 19% and 12% respectively. For lung, stomach, colo-rectal and oesophageal cancer, the potential reductions were 8%, 12%, 2% and 13% respectively.

**Table 8-6 Burden of Disease, attributable mortality and disability for fruit and vegetable intake in Slovenia, 2000**

Population Attributable Fractions (% DALYs)	Male								Female								Total		
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	Male	Female	All
Ischaemic heart disease	-	-	29%	27%	22%	20%	16%	12%	-	-	29%	27%	19%	20%	16%	13%	20%	17%	19%
Ischaemic stroke	-	-	18%	17%	14%	12%	10%	8%	-	-	19%	17%	12%	12%	11%	9%	12%	11%	12%
Trachea, bronchus and lung cancers	-	-	12%	11%	9%	8%	7%	6%	-	-	12%	11%	7%	8%	7%	6%	8%	8%	8%
Stomach cancer	-	-	18%	17%	14%	12%	10%	8%	-	-	19%	17%	12%	12%	11%	9%	13%	12%	12%
Colon and rectum cancers	-	-	2%	2%	2%	1%	2%	0%	-	-	2%	2%	1%	1%	2%	0%	2%	1%	2%
Oesophagus cancer	-	-	18%	17%	14%	12%	10%	8%	-	-	19%	17%	12%	12%	11%	9%	13%	11%	13%
All causes	-	-	0%	2%	4%	4%	4%	3%	-	-	0%	1%	1%	3%	3%	3%	3%	2%	2%

Attributable Deaths	Male								Female								Total		
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	Male	Female	All
Ischaemic heart disease	-	-	0	11	54	70	75	46	-	-	0	2	8	25	66	104	256	205	461
Ischaemic stroke	-	-	0	2	7	15	24	14	-	-	0	1	2	9	31	42	61	85	146
Trachea, bronchus and lung cancers	-	-	0	2	15	22	18	2	-	-	0	1	3	4	6	2	59	16	75
Stomach cancer	-	-	0	2	6	8	10	4	-	-	0	1	3	4	6	4	29	19	48
Colon and rectum cancers	-	-	0	0	1	2	2	0	-	-	0	0	0	1	2	0	5	4	9
Oesophagus cancer	-	-	0	0	5	4	2	1	-	-	0	0	0	1	1	1	13	2	15
All causes	-	-	0	17	88	120	131	66	-	-	0	5	17	44	112	153	423	330	753

**Table 8-6 (continued) Burden of Disease, attributable mortality and disability for fruit and vegetable intake in Slovenia, 2000**

Attributable YLLs	Male								Female								Total		
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	Male	Female	All
Ischaemic heart disease	-	-	0	248	807	614	368	85	-	-	0	40	122	236	352	180	2122	929	3051
Ischaemic stroke	-	-	3	44	99	128	115	26	-	-	0	19	34	89	166	75	416	384	800
Trachea, bronchus and lung cancers	-	-	0	49	221	192	91	5	-	-	0	25	48	38	31	5	558	147	705
Stomach cancer	-	-	7	38	89	71	48	7	-	-	0	26	50	37	35	8	259	156	415
Colon and rectum cancers	-	-	0	5	19	15	11	0	-	-	0	4	6	10	11	0	49	30	80
Oesophagus cancer	-	-	0	9	71	39	12	2	-	-	0	0	6	7	3	1	132	18	150
All causes	-	-	10	392	1307	1057	646	125	-	-	0	115	266	416	597	269	3537	1663	5200

Attributable DALYs	Male								Female								Total		
	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	0-4	5-14	15-29	30-44	45-59	60-69	70-79	80+	Male	Female	All
Ischaemic heart disease	-	-	7	290	906	666	387	88	-	-	14	57	147	261	370	186	2343	1035	3378
Ischaemic stroke	-	-	3	116	233	286	192	35	-	-	0	61	91	201	280	99	865	732	1597
Trachea, bronchus and lung cancers	-	-	0	50	227	197	94	5	-	-	0	26	49	39	32	5	573	151	724
Stomach cancer	-	-	7	39	92	74	50	8	-	-	0	27	52	39	36	9	269	162	431
Colon and rectum cancers	-	-	0	5	23	18	13	0	-	-	0	5	8	12	13	0	59	37	96
Oesophagus cancer	-	-	0	9	73	40	13	2	-	-	0	0	6	7	3	1	136	18	154
All causes	-	-	17	509	1554	1279	750	137	-	-	15	176	353	559	734	299	4245	2136	6381

## ***Strengths and limitations of estimating the Burden of Disease for low fruit and vegetable intake***

It is important to have detailed knowledge of the magnitude and distribution of diseases, injuries, and their risk factors when developing strategies designed to improve population health. This information is needed to assess the scale of the population health needs, to set targets to achieve, and to monitor progress towards them. The CRA methodology has been designed to allow consistent assessment of a wide range of diverse exposures. By describing the exposure of populations to risk factors and assessing the consequences for the health of those populations, it seeks to provide a comparable source of information for policymakers<sup>63</sup>. This is an enormous challenge and, despite recent efforts to measure disease burden throughout the world, the worldwide burden of disease attributed to poor nutrition cannot yet be quantified precisely. This is partly due to the considerable methodological difficulties involved.

One of the major limitations is that dietary exposure is difficult to measure, reflecting the limitations of various methods used for dietary ascertainment <sup>273 275</sup> (see chapter 3 for further discussion). As was noted previously, the biggest issue facing the assessment of exposure to the risk factor ‘low fruit and vegetable intake’ is that the collective term ‘fruit and vegetables’ comprises a very heterogeneous group of foods that differ among countries and cultures. Even in a ‘typical’ western diet, this group includes a wide variety of roots, leaves, stems, fruit, and seeds that varies over time and place <sup>191</sup>. The food content of potentially important dietary components depends on numerous factors such as preparation method, variant of product, growing conditions, and storage conditions – a factor of increasing importance as commodities are transported globally to ensure year round supply in industrialised countries. In spite of this complexity, it was decided to keep fruit and vegetables as a single entity for two main reasons. First, there remains uncertainty as to which components of fruit and vegetables would confer a beneficial effect <sup>504</sup>. Second, pragmatically, obtaining intake data for specific foods would have been even more difficult than for fruit and vegetables taken together.

Notwithstanding the spread of the global economy, the pattern of consumption of fruit and vegetables remains seasonal in many countries, with evidence that this may be linked to levels of cardiovascular disease <sup>5</sup>. It is possible that the consequences for disease of an annual cycle of seasonal excesses and out-of-season shortages (as in the

less economically developed countries of the former Soviet Union) may be quite different to the effects of consuming a similar annual level where counter-seasonal supplies ensure that there is no period of very low consumption (as in the affluent countries of north west Europe and North America which import large quantities of fresh fruit and vegetables). In the absence of information on seasonal variations in fruit and vegetable intake, it must be assumed that the estimates obtained (assumed to represent long-term annualised average fruit and vegetable intake) predict disease risk. However, as noted previously, the need for caution is illustrated by the case of alcohol, where risk of cardiovascular disease appears to be more sensitive to the pattern of alcohol consumption over time as well as the total amount consumed <sup>4 505</sup>.

In this project, as discussed previously in chapter 3, data collected at the individual level are prone to various sources of bias and their quality and validity depend on the ability and willingness of each individual to provide accurate information on his/her intake <sup>506 507</sup>. For example, the high fruit and vegetable intakes observed in Europe A sub-region and Western Pacific A sub-region may represent true elevated intakes. However, they may also suggest conscious or unconscious over-reporting of intakes by survey respondents <sup>188</sup>, although caution is needed when making this assumption as little is known of social desirability bias in the reporting fruit and vegetable intakes and of its potential social and cultural determinants. The reported intakes in some countries within these sub-regions were indeed greater than expected (particularly the United Kingdom and Germany). It is possible that recent public health campaigns, such as those that took place in Finland <sup>189</sup> coupled with changes in the retail trade, and thus in marketing and distribution of fruit and vegetables, might have helped improve dietary habits in these populations, in line with the striking improvements in cardiovascular mortality that they have experienced.

Other difficulties associated with the use of survey data include the conversion of food frequencies into mean intakes in surveys that used food-frequency questionnaires and the limitations and completeness of the various computerized food analysis software used in different countries. Finally, it is possible that survey respondents were not entirely representative of the reference populations, even though most data were from nationally representative surveys of dietary intakes. For example, a lower socio-economic status has been linked with lower intakes of fruit and vegetable intake in Europe <sup>508</sup> and lower response rates in health surveys.



## ***Estimating disease burden in Slovenia***

Where there were limited or no intake data available, food availability statistics were used for global sub-regions and for the Slovenian national estimates. Hence, these estimates may have been influenced by the sources of uncertainty affecting availability data (as discussed in chapter 3) <sup>157</sup>. As noted previously, estimation of the net availability of vegetables is complicated in many countries by factors such as non-commercial production and uncertain losses to animal feed, spoilage and waste<sup>157</sup>. However, the FAO performs external consistency checking using supplementary information such as household survey results as well as the application of relevant technical, nutritional and economic expertise in an attempt to eliminate these potential deficiencies. In Slovenia, the food balance sheet data is subject to national verification to particularly to take account of the large amount of small-scale non-commercial production that occurs across the country (see chapter 10 and 11 for more details of the agricultural production systems in Slovenia). In producing the disease burden estimates, three years of data were used in order to reduce the effect of potential yearly variations in coverage and accuracy.

The methods to derive intakes from availability statistics, used to estimate the burden of disease in Slovenia, clearly have major limitations, including the current lack of information on the most accurate adjustment factors and the influence of the population structure of the sub-regions on the estimates of intake distribution among genders and age groups. Differences in population structures both in Slovenia, and in some sub-regions of the GBD, could make the estimates using food availability statistics less reliable, particularly in population strata with relatively smaller sample sizes such as in the elderly. The methods used to obtain final GBD regional estimates and final Slovenian estimates of mean fruit and vegetable intake and standard deviations (required by the CRA methodology), including the extrapolations and assumptions made when pooling data and when combining survey and FAO data, are further potential sources of error. These include errors due to extrapolating data not in the required format, data missing for some population sub-groups, standard deviations unavailable (as discussed in chapter 3). In Slovenia, there was potential for errors to arise given the use of Italian survey data, as noted above.

Finally, in the GBD study, it is possible that the current WHO grouping of countries did not reflect well the heterogeneity of exposure and disease experience in each sub-

regional grouping (e.g. combining northern European and Mediterranean countries although they have very different disease and intake patterns).

Given so many limitations there were two options with regards to the assessment of both the global and national burden of disease attributable to low fruit and vegetable intake: (i) either exclude countries or regions without good exposure level data, or (ii) use clear assumptions and extrapolations that would stimulate the need for better data collection and further research in all countries and regions. If the first approach, to exclude countries without national survey data, had been used it would have meant that the burden of disease estimations for Slovenia could not have been produced, and globally that the focus of nutritional epidemiological research would continue to be concentrated on developed countries. This did not seem a defensible public health approach knowing that the nutrition transition, occurring in all but the poorest countries of the world, is resulting in the replacement of traditional plant-based diets that are rich in fruit and vegetables with diets that are rich in calories provided by animal fats and sugar and are low in complex carbohydrates. This is true of Slovenia, particularly with its accession to the European Union (see chapter 10). Hence, those countries whose dietary patterns are experiencing the greatest changes at present would have been excluded. It is believed that the estimates are produced using the most extensive data set available derived from the best current evidence. They should be interpreted with caution and treated as a first attempt to develop methods that can be used to assess the worldwide burden of disease due to low fruit and vegetable intake, and also to estimate national disease burden for countries such as Slovenia which do not have nationally representative intake survey data.

Two main assumptions underpin the assessment of diet-related ill health: that diet can be a primary cause of disease or cause a reduction in disease, and that the extent of this causation can be measured. Arriving at agreed figures for the extent of causation is not simple. It is clear from the systematic reviews of diet-disease relationships that trying to estimate the impact of fruit and vegetable consumption on population health is complicated not only because dietary exposure is difficult to measure, but also because of the uncertainty that remains as to which constituents of fruits and vegetables are involved in the protective effect.

This highlights the importance of looking beyond the epidemiology to understand the biological pathways that might be involved, something that has been done surprisingly

rarely in epidemiological research on this topic. Indeed, one of the emerging lessons from this study is the importance of integrating biology and epidemiology to create a more comprehensive and coherent picture, with insights from each perspective informing the other. Consequently, as part of the systematic review I reviewed the biological mechanisms that may be involved in the protective effect of fruit and vegetable consumption (chapter 4). There is limited, although growing understanding of the complex biological pathways through which fruit and vegetables act and of differences in bioavailability of any active components. Given the wide range of bioactive factors in fruit and vegetables, it is plausible that a varied diet has both generic (e.g. antioxidant) and disease specific (e.g. tumour suppressor) effects. In addition, it is likely that there will be differences in genetic susceptibility, in particular because of different levels of activity of key metabolic pathways. This lack of understanding clearly makes intervention studies of fruit and vegetable intake especially difficult to conduct and to date there have only been a few secondary prevention trials of fruit and vegetable based diets mostly in ischaemic heart disease<sup>247 251 260 509</sup>. It also helps to explain the disappointing findings of trials of selected antioxidant and vitamin supplementation that have shown no effect on mortality, cardiovascular events or cancer<sup>239 260</sup>. Nonetheless, the systematic reviews have shown that there is now a substantial and growing body of evidence of a protective effect of fruit and vegetables from well-designed cohort studies in a range of populations<sup>13 32</sup>. Although scientific knowledge strongly confirms the possibility of a causal relationship between fruit and vegetable intake and disease, there were numerous problems estimating the size of the hazard. Estimates of hazard size in individual studies were adjusted for confounding as much as possible. However, there remains considerable uncertainty about the validity of extrapolation from a limited number of studies (mostly in Western Europe, the USA and Japan) to a wider range of populations. This was of less concern in the Slovenian calculations as many of the epidemiological studies cover diverse European populations. It is perhaps easier to confirm summary measures of relative risk for more straightforward or proximal risk factors (such as blood pressure and smoking) compared with more distal factors such as fruit and vegetable intake.

## **Conclusions**

This chapter has presented estimates of the burden of disease due to low fruit and vegetable intake both globally and for the Republic of Slovenia. The GBD work

provides timely objective information of the magnitude of risk factors and health outcomes for all regions of the world and the CRA pioneers comparable methods which allow a wide range of proximal and distal determinants of health to be assessed in a uniform manner. This has allowed the population health effects of fruit and vegetable intake to be compared directly with the effects of other risk factors including smoking, air pollution, obesity, and unsafe sex for different regions of the world.

This chapter has also explored the potential weaknesses of the methods. However, despite the potential limitations of the GBD study, it is important to recognise the benefits that the presentation of comparable information can bring to public health policymakers. This will be discussed in Chapter 9.

## **Chapter 9 The use of burden of disease studies to inform policy**

This chapter discusses the strengths and limitations of the burden of disease (BOD) methodology as an evidence-based approach to informing public health policy.

Prior to the WHO Burden of disease analyses, there were no standardized compilations of comparable information on the combined extent of morbidity, disability or death in different populations of the world. Information at global or regional level on behaviours and exposures that are important risk factors for disease has also been limited. There is a need for standardised summary measures of population health because, in general, weak information about a health problem is often interpreted in policy debates as meaning that a problem is unimportant, which often in turn perpetuates the lack of information.

Fruit and vegetables as a dietary risk factor exemplify this issue. For many years, fruit and vegetable intake was not considered a significant risk factor for cardiovascular disease, so that public health policies in European countries were focused on smoking, high plasma cholesterol, and high blood pressure, with obesity and fat intake as the only dietary risk factors. Often, in the absence of standardised comparable data, health statistics are provided to decision-makers and the public by advocates with specific agendas, with the result that the information they provide is filtered or biased in its presentation.

The development of burden of disease studies, and the use of DALYs that is integral to them, has made a major contribution to public health policy formation. They were the first attempt to provide independent information on the magnitude of health problems globally, and have been used extensively by WHO, the World Bank<sup>99 144</sup> and by national governments<sup>20</sup> and regional agencies to determine disease priorities<sup>510</sup>.

### ***Limitations of the burden of disease approach***

The GBD approach has, however, proven controversial and there has been a growing critical literature focusing on the use of DALYs and burden of disease studies. The range of criticisms is not solely focused on scientific concerns but include ethical debates about the construction of the methods and their application. The nature of the critiques of burden of disease studies can be summarised under four key themes; the appropriateness of the weighting used, whose values should be represented in

constructing the estimations, data quality and the usefulness of DALYs for decision-making (Table 9-1).

**Table 9-1      Critiques of the use of DALYs in Burden of Disease Studies**

Critique	Specific concerns
Whose values should be represented?	Conceptions of 'health', 'disease' and 'death'
	Role of experts
	Universality of disability weights
	Gender bias
	Human rights
	Integrating equity
Appropriateness of weights used for calculating DALYs	Life expectancy
	Age
	Future time
	Disability
Data Quality	Estimation from imperfect data sources
DALY's usefulness for decision-making	

The majority of criticisms of the estimation and use of DALYs centre on the various discussions about the use of values, explicitly and implicitly. One critic has stated that perhaps this is because *‘the initial presentation of the concepts as a tool in a World Bank policymaking document, already demonstrates that it is difficult to separate the critique of the methodology itself from its application in a politicised debate on health reform’*<sup>511</sup>.

**Appropriateness of weighting and discounting approaches**

Choices in the construction of summary measures of population health implicitly or explicitly reflect underlying preferences. DALYs, the most widely used summary measure, make an implicit assumption that the relationship between measures of disease and the resulting burden is equal for all in a population and while preferences for investing in younger versus older age groups may be included by applying age weights, this tends to be hidden by the estimation of a single figure<sup>512</sup>.

The choice of weights to provide a means of combining disease and disability with mortality has probably been the most controversial aspect of DALYs. The DALYs approach ignores traditional research into inequalities and health based on intra-individual and social group differences within populations<sup>513</sup>. The use of an idealised life expectancy in calculating the burden of disease is not directly relevant to national planning and tends to foster, rather than reduce, inequity between countries. In effect,

older people in richer countries are accorded more weight than younger people in poorer countries.

The value of living a healthy life at different ages during a person's lifetime may also have become confused with the value of time and the greater likelihood that older people will be disabled. Therefore, the impact of disability at different ages may have been double counted. As the developers of DALYs rejected human capital theory for valuing age<sup>93</sup>, it seems inconsistent of them to draw on the same theory for valuing future time. For DALYs, a three percent annual discount rate for valuing future time was chosen arbitrarily, with little empirical evidence to justify it. Nor is a standard three percent likely to represent global preferences, even if it was possible to aggregate such preferences. Hence it could be argued that two important aspects of the method used to derive the weights applied to conditions giving rise to disability are based on ethical principles that are not widely accepted.

These problems are further compounded because, in practice, few burden of disease studies report explicitly the assumptions used, or test the sensitivity of results to these assumptions. Although not an issue with the GBD, this will limit comparability between national studies, although comparability is one of the key arguments for conducting such studies<sup>144</sup>.

### **Whose values are used in constructing DALY estimates?**

The other major critique is disagreement about whose values are, and should be represented. This reflects two issues; how to have an explicit debate and consequent process to explore the societal values that should be used (those of patients, carers, professionals or the general public), but also the valuation method that should be used. Valuation methods differ among summary measures of population health, with implications for estimation of how much a specific summary measure will accentuate the importance of morbidity and disability relative to mortality.

In the GBD programme, the reliance on expert opinion for the development of the weights used for each condition involves assumptions (frequently untested) about the relationship between the condition and factors such as age, sex, and interactions with other diseases and conditions<sup>512</sup>. This is in contrast to other summary measures of population health, such as HALE, which use population-based health surveys. The wide ranging debate about definitions of 'illness' and 'health' states and how to value

them is beyond the scope of this thesis. However, it is important to mention that the DALY approach has faced increasing criticism by its continued focus on a 'biomedical' model of disease<sup>514</sup>. It is clearly a complex area of research to understand how people experiencing disease give accounts of their condition. However, DALYs have rejected definitions arising from those with illness and exclusively use the value preferences of English-speaking health professionals to determine disease weights, and hence indirectly global resource allocations.

The DALY approach also ignores research showing that the understanding and experience of disease and sickness depends fundamentally on context. Disability weights are therefore unlikely to be universal. Hence assumptions that these weights are universal must surely lead to inappropriate conclusions about the disease burden, and the most effective interventions in a region or country<sup>512</sup>.

One of the most inequitable aspects of the weighting system is the value that is given to those that have the least ability to return to full health. This has meant that this group, which usually includes the poor and elderly, have a lower perceived claim on health resources.

### **Coherence of summary measures of health**

Although the World Health Report 2000<sup>97</sup> set out to measure performance of the health system, it did so in part using standardised measures of population health originally developed for the global burden of disease study. It has been argued that it is inappropriate to attribute differences in overall mortality (or disability adjusted life years) solely to one causal factor<sup>515</sup>, whether that be the performance of the health system in the World Health Report 2000<sup>97</sup>, or a single disease risk factor in the World Health Report 2002<sup>9</sup>. These applications of summary measures of population health by WHO simplify the links between health determinants and health outcomes. They ignore evidence that levels of disability and premature mortality are determined by a complex range of proximal and distal determinants including political interventions, wealth and income distribution.

The limited focus of DALYs on disease and some aspects of disability also means that many benefits of interventions that improve health and welfare are not measured. It also means that the only way that co-morbidity in an individual is included is by adding up weights for each disease separately. This means that the benefits expected from an



intervention may not be realised because it is not linked to the reality of the disease and illness within the population. This can be said of the calculations of the burden of disease due to low fruit and vegetable consumption, as this is just one risk factor for cardiovascular disease and cancer. There have been some initial attempts to estimate the reduction in global disease burden from tackling a number of risk factors for major diseases, such as cardiovascular disease<sup>500</sup>. However, these initial attempts are rather simplistic and do not take into account the complex causal web of proximal and distal risk factor interactions known to occur.

### **Data quality and use of evidence**

Another issue that is rarely mentioned in reports by advocates of the use of burden of disease studies is the concern about data availability and quality. There have been criticisms that due to the lack of data, many estimates and extrapolations are used in burden of disease studies which are often not explicitly mentioned when reporting the outputs of the analysis<sup>516 517</sup>. Several commentators have argued that projects using composite measures, such as the Global Burden of Disease and the World Health Report 2000, rely on an unduly narrow evidence base<sup>516</sup>. The main problem is a lack of data from many countries, both in terms of the levels of disease but also the level of risk factors. For example, the World Health Report 2000<sup>97</sup> was unable to obtain data from which to calculate the index of health inequality for 133 of 191 countries (70%)<sup>516</sup>. It has also been argued that methods and underlying assumptions used to input missing values are inadequately specified<sup>517</sup>. For example, the data for countries in Africa used in the 2000 World Health Report were extrapolations from mortality in urban South Africa. The use of modelled data for Russia missed the subsequent finding, using survey data, that there was an unexpectedly large burden of disability among older women compared to men<sup>518</sup>. It is very easy to report the final burden of disease figures, as this thesis does in chapter 8 for low fruit and vegetable intake both globally and nationally for Slovenia, without open reporting of the data sources and their reliability (as discussed in chapters 3-8). This is a valid criticism as policymakers are keen to have the 'headline' figures and do not want to be bothered with pages of scientific debate about the reliability of the analysis. Hence there has been a tendency for results from the Global Burden of Disease study to be quoted without any discussion of the assumptions, or limitations.

Lack of individual data on risk factor distribution by age, gender and region was a problem for a number of risk factors in the CRA project<sup>519</sup>. For the analysis of the global burden of disease due to fruit and vegetable intake, nationally-representative individual survey data were only obtainable from only 26 countries (chapter 3), although in six of the 14 regions this covered over 69% of the regional population. The proportion of the sub-regional population covered by the survey data used is given in Table 3-6. As noted previously, given so many limitations with the data available on fruit and vegetable intake, there were two options with regards to the assessment of the global burden of disease undertaken for this thesis: either exclude regions without good exposure level data (which would have meant that the focus of nutritional epidemiological research would continue to be concentrated on developed countries) or use clear assumptions and extrapolations that would stimulate the need for better data collection and further research in all regions. I believe that the estimates provided are the most extensive data set available, derived from the best evidence currently available, but they should be interpreted with caution and treated as a first attempt to develop methods that can be used to assess the worldwide burden of disease due to low fruit and vegetable intake.

Both measures of healthy life expectancy (such as disability-adjusted life expectancy), and measures of health gaps (such as DALYS) are advocated as superior measures of health than life expectancy or mortality because they incorporate measures of disability. However, as data on levels of disability are available in very few countries, life expectancy in countries with no data has been reduced by a factor that is the same (within each age band) for each country within groups that have similar levels of life expectancy<sup>520</sup>. In countries where disability surveys are available, there was frequently a mismatch between the values obtained from the surveys and those estimated using the GBD methodology. This was attributed to national differences in norms and expectations and the GBD data was used to rescale the survey data<sup>521</sup>. However, there is an argument that DALYs and DALE add nothing to improve understanding compared to more transparent measures such as life expectancy.

Murray et al have, however, argued that the use of such estimates for 'missing' data is common in international economic comparisons<sup>522</sup>, and that they have reflected concerns about the use of estimated data for estimating disease burden by extensive use of uncertainty estimates<sup>519</sup>.

### **Usefulness of burden of disease studies for decision-making**

The central concern of this thesis is the role of research in influencing policy. Hence it is important to reflect on the usefulness of DALYs in burden of disease studies for decision-making, compared with other summary measures of population health. Although there are many summary measures to estimate disease burden, the differences between them is not often discussed. A US study constructed life tables using US National Centre for Health Statistics data<sup>523</sup>. These were then adjusted for quality of life using prevalence data from the National Health Interview Survey and health related quality of life scores obtained from the Quality of Well being Scale. Estimates of burden of disease for common diseases were made using, QALY (quality adjusted life years) and YHL (years of healthy life) measures. Separate estimates were made for low and higher income groups, and different ethnic groups. The study found that the burden of disease estimates differed substantially between the three summary measures. Rank order of disease burden was not consistent across the different measures, with discrepancies being greater when socio-demographic groups were used<sup>523</sup>. The lack of standardization among summary measures and their results has important implications for public health policy application. Diseases and demographic groups will receive different priorities for interventions or research depending on which summary measure is used to inform decision-making. Several commentators have questioned whether the resources committed to the production of the burden of disease studies, and their sequelae nationally and internationally, might not have been used more effectively in other ways<sup>517</sup>.

### ***Strengths of the burden of disease approach***

Although there have been extensive academic discussions about the limitations of DALYs and the burden of disease method, these seem to overlook its original design and purpose. A major advantage of the GBD method is that it has been designed for use in a variety of countries with very different levels of data availability. It has been argued that DALYs, despite their limitations, can still be used as an aid in health planning as they enable a more informed debate on social values that influence resource allocation, or identify health problems that may be neglected<sup>524</sup>.

Methods used to generate summary measures of population health now belong to the core body of health statistics<sup>96</sup>. They are widely used for many purposes, and have the ultimate goal to support policy decisions in the allocation of resources for prevention.

health care and research. For such priority setting, information on the relative size of health problems and risk factors is an important part of the evidence needed. The debate on such measures has moved beyond whether they are useful and instead asks which summary measures are useful for a given purpose. There is obviously no one approach that is best in all situations. Nor will summary measures ever replace the need for more detailed health data.

One of the most important contributions of this method is not the end result, in this case the DALY estimate itself, but the way it has forced authorities to address the lack of epidemiological and demographic data to produce it. The Burden of Disease approach promotes the application of uniform definitions and collection of missing information in more systematic ways. This is especially important in relation to measurement of consumption of fruit and vegetables and other foods, given the lack of individual level data in many countries. Thus, summary measures have a role not only in setting public health and research agendas, but also in setting agendas for collection of international comparative data.

## **Conclusions**

Summary measures of population health, such as DALYs, are increasingly being used to monitor the health status of countries and regions and to evaluate health interventions. However, as they are based on aggregate indicators of individual health they simply describe health in a population. They have limitations as a means to analyse of population health. This can be seen in their application to the study of the burden of disease due to dietary risk factors. In the case of fruit and vegetables, estimating the global, regional and national burden of disease due to contemporary low fruit and vegetable intake was important in the process of raising the issue of fruit and vegetables further up the worldwide policy and research agenda. It provided information about fruit and vegetables as a dietary risk factor for cardiovascular disease and some cancers in a form that allowed fruit and vegetable consumption to be compared directly to other risk factors (such as high blood pressure, serum cholesterol, obesity and smoking)<sup>63 500</sup>. However, its usefulness was limited as a source of information for decision-makers as it is unable to provide information about what should be done to improve intake, and hence public health.

DALYs only partially reflect the impact of disease on people's lives. They offer at best a limited picture of the size of a problem. They are useful if the intention is to eradicate a disease or to ascertain the broad magnitude of resources required for care<sup>525</sup>. Estimates of the burden of disease are not a sufficient basis for detailed resource allocation, or decisions in complex policy scenarios such as food or agriculture policy, as they say nothing about how interventions are likely to reduce the problem, or about the opportunity cost of allocating money to one disease rather than another. Hence in reality they are unlikely to aid decision-makers make decisions about efficient use of resources. In this thesis it was considered inappropriate to apply burden of disease methods to analysing the CAP fruit and vegetable regime, because it would have entailed reducing aspects of the CAP policy to an oversimplification. For example, one could use the burden of disease model to estimate what would happen if EU price support for fruit and vegetable production was discontinued. The assumption would be that removal of EU price support would lead to decreased prices, which would increase consumption of fruit and vegetables. However, in reality this does not take full account of the complex production and retail system operating at the EU level, so any simplistic modelling at this level is likely to be of dubious relevance to the behaviour of the actual market system<sup>526</sup>.

Finally, as has been shown in the calculations in this thesis, burden of disease studies have different implications for decision-making at national and international levels. DALYs offer a broad-brush approach to estimating the impact of interventions or risk factors (as here) in different regions of the world based on expert views. They have become of great interest to international decision makers such as the WHO and World Bank. At a national level, burden of disease studies vary in their importance. In low income countries, the World Bank ties loans to the calculations of DALYs. However, in middle and high-income countries, such as Slovenia, DALYs may be interesting but offer little scope to change national priorities.

As can be seen in the case study from Slovenia, estimation of the disease burden for low fruit and vegetable intake did not provide new insights to policymakers. The Ministry of Health was aware of the health effects of low fruit and vegetable consumption in Slovenia and already had a 400g/day fruit and vegetable goal as a key component in both their food-based dietary guidelines, and the National Food and Nutrition action plan. What the Ministry of Health in Slovenia required was

information on how food and nutrition would be affected by policy change, in this context, the effect of joining the EU and adopting the CAP. Burden of disease analyses could not contribute to this debate. This required two other types of information; predicting the possible health consequences of policy change, and gathering evidence of effectiveness on any interventions that may be used to tackle the potential effects of policy change.

This requires a broader evidence-based approach than that encompassed by burden of disease studies. Health impact assessment has been promoted as one evidence-based tool that can analyse the potential effects of policies or programmes (see chapter 2). This approach was piloted in Slovenia to assess the new agriculture and food policies that would be implemented due to EU accession. The methods and results of this HIA process will be discussed in Chapters 10 and 11.

Despite the acknowledged limitations of the methods, the estimation of the global burden of disease of low fruit and vegetable consumption has been important in informing global policy development, influencing development of a WHO fruit and vegetable promotion strategy <sup>527</sup>. However, in Slovenia, food policy development required a wider range of evidence sources which provided more information on the specific national context.

**PART 3: HEALTH IMPACT ASSESSMENT OF FOOD  
AND AGRICULTURAL POLICY**

## **Chapter 10 Health Impact Assessment of the EU Common Agriculture Policy in Slovenia: methods**

This chapter outlines the background and the methods used to apply HIA methods to study the potential health impact of incorporating the EU Common Agricultural Policy into national agricultural and food policy in the Republic of Slovenia following EU accession, focusing on the effect on the fruit and vegetable sector.

### ***Background to the HIA in Slovenia***

The research to develop and conduct a HIA of national agriculture and food policies was started in March 2002, working with the Ministry of Health in Slovenia <sup>528</sup>. The main aim was to assess the potential effect of the Common Agricultural Policy (CAP) on population health. There were two main reasons why I selected Slovenia as the most appropriate country in which to develop research into HIA of national agricultural policy. The main reason was that Slovenia's application to join the EU in May 2004 (Figure 10-1) provided a unique opportunity to prospectively assess the influence adoption of the CAP legislation would have on national agricultural policy. However, there were also national Slovenian concerns and priorities that supported development of the HIA work in Slovenia rather than other accession countries. The Ministry of Health was in the process of developing a national food and nutrition action plan in line with an agreed European strategy <sup>22</sup>. This Strategy included agricultural sector involvement and was due for completion in 2003-2004. More generally, there was high-level political support for assessing the health effects of agricultural policy at a national level that facilitated the research; such political factors were not apparent in other accession countries.

### ***Agricultural Policy in Slovenia prior to accession***

In Slovenia, agriculture contributes about 3-4% of the GDP<sup>529</sup>. This is much higher than the EU average, with only Greece, Ireland and Portugal of the former EU-15 having larger proportions of their economy dependent on agriculture.

Slovenian agriculture is characterised by small family farms <sup>529</sup>. These traditionally are not specialised with low intensification and productivity. Many are run part-time with farmers having other jobs <sup>530</sup>.

Slovenia is a net importer of food, being approximately 70% self sufficient. Of the range of agricultural sub-sectors, the country is only self-sufficient in milk, poultry and



meat production. The milk and poultry sectors currently over-produce by 10-20%. Wheat, maize, and the fruit and vegetable sectors are only producing amounts which achieve 50-70% self sufficiency<sup>529</sup>.

In July 1997 the European Commission concluded that Slovenia still had work to do on its farming legislation to align with the EU (Commission opinion COM (97) 2010 final). The opinion stated that particular effort was required in the following areas:

- Improving structural and rural development policy;
- Enforcing veterinary and phytosanitary rules and infrastructure;
- Strengthening the administrative framework to guarantee the necessary capacity for implementing and enforcing CAP;
- Further restructuring the farming sector to boost competitiveness.

To prepare the agricultural sector for accession an agricultural policy was proposed with strong environmental and social principles which reflected the culture of Slovenian farming <sup>530</sup>. There were three aspects of agricultural policy reform relevant to accession that were adopted:

- National policy reform (to harmonise the policy with the CAP);
- Harmonisation of the legislation with the EU *acquis communautaire*;
- Institution building to support the changes.

Slovenia already had a legal system that was compatible with the CAP as the Agricultural Act had enabled introduction of comparable market organisations, supportive rural development policies, and stricter food safety laws. National changes prior to accession, in response to agricultural policy reform, increased budgetary funds for agriculture, market mechanisms similar to the CAP, direct payments, rural development and ‘pillar 2’ (environmentally focused) initiatives, and pre-accession aid to farmers (see chapter 11).

**Figure 10-1 Map of the European Union showing all 25 Member States: including Slovenia and the nine other new Member States that acceded in May 2004**



Source EU website 2004

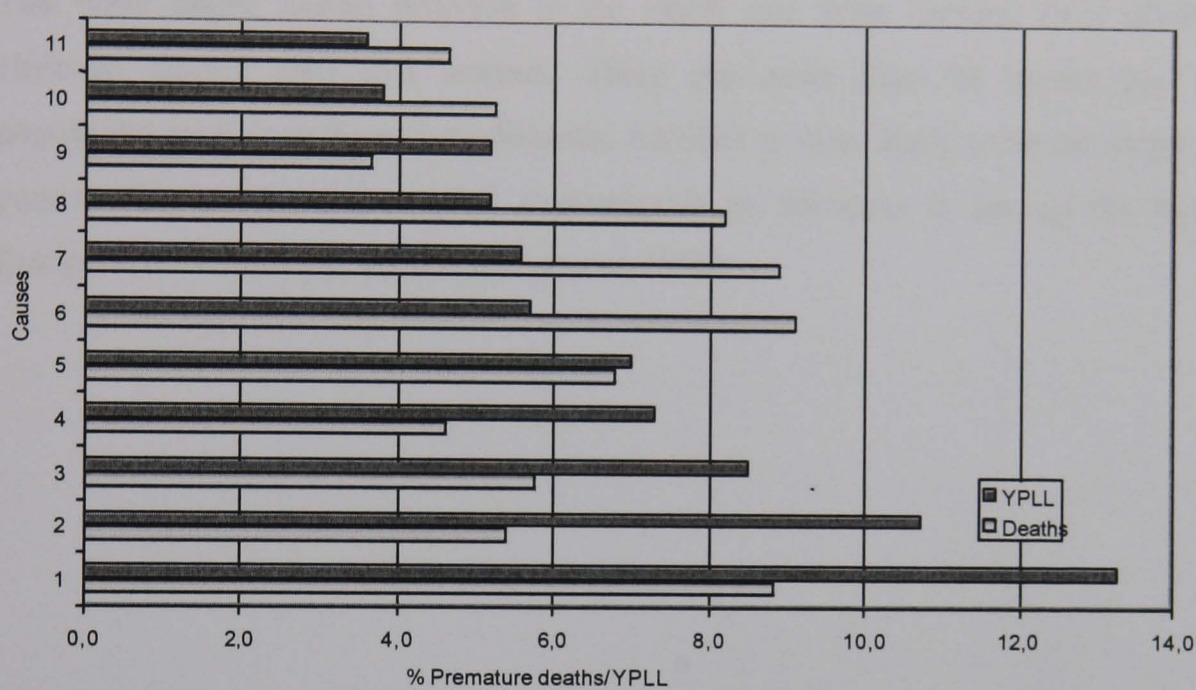
**Population health in Slovenia**

Slovenia has relatively better population health than many of the other EU accession countries. It has mirrored the EU’s steady progress in reducing mortality, although overall life expectancy is still over 2 years lower than the European Union average of 78.3 years<sup>531</sup>. Life expectancy at birth in Slovenia in 2003 was 72.6 years for males and 80.4 years for females. However, a narrow focus on life expectancy does not reveal the full extent of public health challenges facing Slovenia. Morbidity and mortality data show that Slovenia experiences a similar pattern of disease as other countries in Central and Western Europe. Diseases of the cardiovascular system are the most common cause of death in Slovenia, causing almost half of all deaths. Other leading causes of death are cancer, injuries, poisoning, and respiratory deaths. The major causes of premature



mortality are compared in figure10-2. The particular national health concerns that have been identified as priorities are the high mortality rates for stroke, cancers, suicide, injury and poisoning and liver cirrhosis, all of which are much more common than in the EU <sup>532</sup>. Alcohol-related and psychiatric deaths are particularly high, over double the EU average, as can be seen in Table 10-1.

**Figure 10-2 The main causes of adult premature mortality in Slovenia,1997-2001**



Key to graph

- 1 Suicide

2 Transport Accidents

3 non-defined external causes

4 Head injuries

5 Liver diseases

6 Gastrointestinal Cancers
- 7 Ishaemic heart disease (IHD)

8 Lung cancer

9 Undiagnosed cases

10 brain vessels diseases

11 other heart diseases

Source T. Albrecht, 2003

**Table 10-1 Comparison of death rates for selected alcohol-related causes between Slovenia and the EU average (1999)**

	Standardised death rate per 100,000	
	Slovenia (NIPH database)	EU average (WHO HFA)
Suicide	23.35	10
Injury and poisoning	70.80	31.8
Liver cirrhosis	34.08	13.6

Source: WHO Health for All database 2002 and Institute of Public Health 2001

The suicide rate in Slovenia has been among the highest in the world for over 20 years. National data have shown that suicide is most common among marginalised groups,

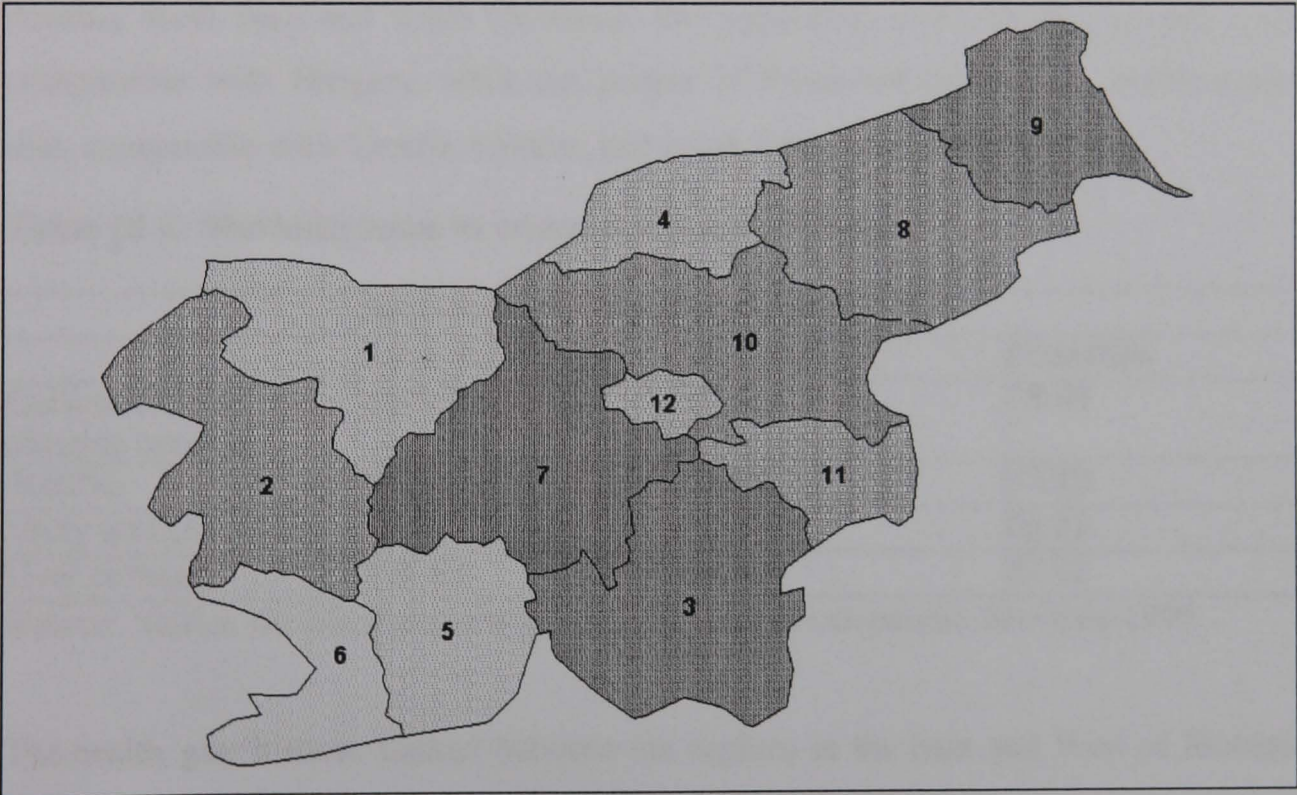
particularly those living in poverty or with only primary education, semi-skilled workers, unemployed and alcoholics <sup>533</sup>. External causes of injuries and poisonings are also a major public health problem. Injury and poisoning are the leading cause of death between the age of one and about 45 years of age. Even though the number of deaths caused by injury and poisoning has decreased slightly from 1986-1999, Slovenia still has one of the highest mortality rates in Europe, exceeding the EU average by 100%. The other major health problem is the death rate from chronic liver disease and cirrhosis among men and women. There are more than 30 deaths per 100,000 population each year from liver diseases. Alcohol is most likely to be the single biggest contributing cause, and alcohol consumption in Slovenia is among the highest in Europe (10.38 litres per person per year in 1998).



**Figure 10-3 Map of administrative regions of Slovenia (as of May 2005)**

- Key:
- 1. Gorenjska
  - 2. Goriška
  - 3. Jugovzhodna Slovenija
  - 4. Koroška
  - 5. Notranjsko-kraška
  - 6. Obalno-kraška
  - 7. Osrednjeslovenska
  - 8. Podravska
  - 9. Pomurska (Equivalent to Prekmurje/ Pomurje- the region considered in this thesis)
  - 10. Savinjska
  - 11. Spodnjeposavska
  - 12. Zasavska

*NB This is a new regional classification since the completion of the health impact assessment study. Regions 2 and 5 were previously considered together as the Littoral region (known as Primorska)*



**Regional variation in health status**

There are regional differences in life expectancy, morbidity and mortality in Slovenia which correspond to indices of relative poverty <sup>531</sup>. The difference in life expectancy between the least developed regions and central Slovenia is 3 years. The correlation coefficient between income and life expectancy across Slovenian municipalities is 0.7. The correlation between life expectancy and education is slightly lower but still statistically significant <sup>534</sup>.

The HIA undertaken in this thesis concentrated on three regions, Pomurje (also known as Prekmurje), Gorenjska, and Primorska (Figure 10-3). These regions were selected because of the health (Table 10-2) and socio-economic inequalities (Table 10-3) between them. These regions also have very different historical and cultural backgrounds, and this is reflected in the dominant dietary patterns. For example, the population of Gorenjska typically consume a mid European diet, comparable with Austria, north Italy and south Germany, the population of Promurje consume a diet comparable with Hungary, while the people of Primorska consume a Mediterranean diet, comparable with Croatia, Greece, and south Italy (see chapter 12).

**Table 10-2: Mortality rates in selected regions of Slovenia**

	Standardised death rate per 100,000		
	Pomurje	Gorenjska	Primorska
Cerbrovascular disease (stroke)	122.78	72.63	74.69
Suicide	34.01	28.56	15.89
Injury and poisoning	41.48	39.36	59.32
Liver cirrhosis	135.48	24.79	17.92

Source: Office for Macroeconomic Analyses and Development, Slovenia 1999

The health gap is most marked between the regions in the East and West of Slovenia, affecting many causes of morbidity and mortality, including cerbrovascular disease, suicide, liver cirrhosis. The north-east region, Pomurje, which has the highest all-cause mortality and mortality from cardiovascular disease, poisoning and accidents and suicide, is also the region with the largest agricultural sector in the country, and so most likely to be affected by the CAP after accession (Table 10-2). The east has a higher percentage of the population living in rural and agricultural communities.

The reasons for the regional health differences are not entirely clear, but they are also mirrored by regional differences in socio-economic status and educational level (see

table 10-3). In the 3 regions considered for the case study unemployment is higher, life expectancy is lowest and people have the lowest level of educational attainment in Pomurje.

**Table 10-3. Selected regional differences in socio-economic determinants of health**

	South Primorska	Gorenjska	Pomurje
GDP (SIT), 1996	1 311 000	1 185 000	998 000
Unemployment (%)	10,6	12,6	18,7
Life expectancy at birth (years)	75,5	73,9	72,1
Years of schooling	9,3	9,2	8,7

Source: Office for Macroeconomic Analyses and Development, Slovenia 1999

**HIA methods**

HIA was proposed as an appropriate approach that could be developed to investigate population health concerns about the implications of the complex changes in agriculture, food and nutrition policy in Slovenia. This was particularly important in the agricultural sector where public health was not on the enlargement agenda as it was not explicitly mentioned in the relevant chapter of the treaty of accession.

The review of the literature showed that no country had prospectively conducted an assessment of the health effects of incorporating the CAP into their national agricultural policy (see chapter 2). Indeed, this was the first time that any country has attempted to conduct a HIA of any proposed national agricultural and food policies. As I was unable to find any appropriate models of HIA of national agricultural policy that I could apply I looked at HIA methods used by governments for different policy contexts (see chapter 2 and discussed further in chapter 12) and adapted the various approaches to the situation in Slovenia.

The HIA followed a standard methodology <sup>125 103</sup>, which had been adapted to the particular context in Slovenia. The HIA consisted of five stages:

- Forming a steering group to decide the scope of the HIA;
- Screening the policy options to clarify the policy being assessed;
- Appraisal, which included both data collection and analysis of likely health impacts. Information collected came from three sources:
  - Participatory stakeholder workshops;
  - Review of research literature relevant to the policy;

- Analysis of Slovenian data for key health-related indicators to profile the population affected by the policy;
- Creating recommendations by prioritising information and evidence from all the sources
- Reporting the findings to a cross-government group in time to influence development of the National Food and Nutrition Action plan.

### **The scope of the HIA**

The project steering group included myself, representatives of the World Health Organization (European Region) specialising in nutrition and HIA, representatives of the Slovenian Institute of Public Health, the Ministry of Health, and the Department of Agricultural Economics at the University of Ljubljana . The main roles of the steering group were to determine the terms of reference and scope of the HIA and to ensure the progress of the various stages of the proposed work. This was guided by a scoping document outlined at the inaugural meeting of the group, which agreed the aims and parameters for the HIA <sup>535</sup>.

The scoping was an iterative process. The scope of the HIA (in terms of breadth and depth of policies considered and time frames) changed after the screening stage when policy analysis gave greater clarity about the feasibility of the proposed HIA.

### **Screening: defining the policies to be assessed**

Screening is the procedure by which projects or policies are selected for HIA. The major difficulty in the initial stages of the Slovenian HIA was clarifying which policy options to assess. Although there were proposals to develop a new agricultural policy and a food and nutrition action plan, these were still at the stage of development rather than firm governmental intentions. To complicate matters, the HIA had to take into account the effect of adopting the Common Agricultural Policy into Slovenian law. At the start of the project this could not be done with any degree of certainty as the nature and amount of common agricultural policy subsidies that Slovenia would be allocated on accession had not yet been agreed. Although the amount of subsidies was resolved in late 2002, the Slovenian government was at that time still in the process of developing the specific policies that this money would be used for. Although the EU CAP is an enormous and relatively inflexible body of legislation, it does allow for some national discretion. The complexities of European agricultural policy and the various



ways that it could be applied in Slovenia made the conduct of a detailed HIA of specific policies very difficult, particularly when the focus of the agricultural policy negotiations between the EU and Slovenia focused on financial assistance for production. The problems can be illustrated by looking at how EU agricultural funding changed during the progress of the HIA. At the start of the HIA the Special Accession Programme for Agriculture and Rural Development (SAPARD) provided financial assistance to support the efforts made by candidate countries as they prepared to participate in the single market and the CAP. For Slovenia the annual SAPARD allocation was € 6.447 million, at 2000 prices. It had to be used to address two priorities:

- improvement of production and marketing structures in agriculture and food processing industries;
- economic diversification and improvement of rural infrastructure.

At a later stage in the HIA, EU leaders at the Copenhagen summit (December 2002) reached agreement with ministers from the 10 candidate countries about the terms of their EU entry, that would take place on May 1<sup>st</sup> 2004. Under the agreement, funding available for all candidate countries was to be fixed at €5.1 billion for 2004-2006, with EU direct aid being phased in over 10 years. The initial negotiating position was that farmers in the new Member States would receive 55% of the support levels of the existing fifteen Member States (EU15) in year one (2005), rising to 100% incrementally by 2010. The consequence of this decision was that each country would have to top up the payments made by the EU to its farmers. Farmers in the new Member States would, however, have full and immediate access to CAP market measures, such as export refunds and intervention measures. Slovenia did somewhat better than the other accession countries, with the total financial inflow into Slovenia for agriculture standing at €80 per citizen. This is the highest figure of any of the new Member States but was still well below the agricultural funding in current EU Member States (e.g. €450 in Ireland, €250 in Denmark, €150 in France). The final agreement between Slovenia and the EU, reached in 2002, was that direct payments would reach 85% of the level of the EU 15 in 2004, rising to 100% in 2007 <sup>536</sup>. Slovenia was thus the only accession country to achieve 100% of direct payments in 2007. However, despite this agreement on levels of funding, the accession negotiations were characterised by three main areas of contention, levels of direct payment to producers.

production quotas and rural development support measures. Hence, the finalisation of the financial support arrangements did not help us to finalise the scope of the HIA.

To clarify the focus of the HIA project, it was decided to concentrate on screening CAP policy options in terms of the criteria outlined in Table 10-1.

No specific screening tool was applied as had been used by some HIA practitioners. For example, the Merseyside guidelines rapidly assess candidate projects or policies using a list of questions that cover five criteria; impacts on human capital, natural resources, environmental protection, social capital and economics<sup>125</sup>. This approach is frequently used where HIA is well established, screening all policies of an organisation in order to target limited HIA resources effectively. As the focus of the HIA in Slovenia was the Food and Nutrition Plan it was only necessary to ensure that the CAP was relevant this. Two methods were used to provide data for screening; documentary analysis of policy documents and research literature, and modelling of likely scenarios after accession.

It was inevitably necessary to ensure the participation of people with a range of expertise. Consequently the HIA project involved the involvement of Dr A. Kuhar and Professor E. Erjavec, agricultural economists at the University of Ljubljana, who were advisors to the Slovenian Ministry of Agriculture and members of the Slovenian Government EU CAP negotiating team. They assisted in constructing economic models and interpreting potential policy scenarios for Slovenia when integrating the CAP requirements into Slovenian national policy<sup>526 530</sup>.

**Table 10-1     Screening criteria used to determine which policies to assess in the HIA**

Health outcomes	The nature of potential health outcomes
	The likelihood of potential health outcomes
	The likely frequency (incidence/ prevalence) of potential health impacts
Economic issues	The likely cost to the economy or markets
	The population groups affected
Strategic issues	Timeliness (i.e. in relation to the CAP negotiations)
	National versus regional impact

Obviously the adoption of the EU CAP was expected to have a large influence on national policy in many sectors, covering a wide range of diverse issues such as land use, food processing, food safety, marketing, rural development, education and re-training of farmers. Although it was acknowledged that many of these could have population health impacts, it was decided that the HIA should concentrate on the effects of the regimes for specific food commodities known to be relevant for important diseases. For this reason, the fruit and vegetable, wine and dairy sectors were selected for analysis. Our policy analysis had to balance the CAP requirements for specific policy regimes against national proposals that emphasised rural development measures such as diversification and environmentally-friendly policies (issues covered by ‘pillar 2’ of the CAP- see chapter 1 and chapter 11 for clarification). Although these national proposals were based on the CAP, it was widely believed that the EU negotiations would prevent them being adopted in full. It was also felt that the HIA must recognise that there are other drivers of policy change in this sector, including cultural and socio-economic change.

**Participatory appraisal**

The most important part of an HIA is collecting and appraising information for the types and magnitude of health impacts that a policy might give rise to. It had been decided that the approach to HIA that would be taken in Slovenia would include both

qualitative and quantitative methods and would collect information from three main sources;

- Participatory stakeholder workshops;
- Review of research literature relevant to the policy;
- Analysis of Slovenian data to identify key health-related indicators to profile the population affected by the policy.

The methods employed to obtain information from each of these sources is described in the following sections.

### ***Participatory stakeholder workshops***

National and regional stakeholders were involved by means of participatory rapid appraisal (PRA) techniques. In the HIA literature these are also known as participatory stakeholder workshops, and are seen as an effective way of consulting a relatively large number of dispersed stakeholders<sup>112</sup>.

The aim of the workshops was to identify the potential impacts on health of a wide range of stakeholder groups, and ways of addressing these impacts. The selection of stakeholders to participate in the workshops was important to ensure that the data elicited during the workshops was not distorted by selection bias. Sampling for qualitative research has different aims and requirements than that used with quantitative research<sup>537</sup>. A non-probability purposive sampling technique was used. This deliberately selected participants to reflect a range of groups within the Slovenian population. The aim was to include as heterogeneous a sample as possible, to represent the diversity of opinion and knowledge on agriculture and food policy. Invitations to participate in the HIA workshops were sent to specific individuals or organisations that had been identified by the Steering Group. Open invitations were circulated amongst public health institutes, a range of non-health NGOs, and community organisations in agricultural regions across the country. People were also asked to suggest to the Steering Group the names of anyone that they thought should be involved. The purpose was to ensure that all relevant stakeholder groups, as identified by both the steering group and other stakeholders, were represented.

The HIA workshops were held in the region of Pomurje, in the north-east of Slovenia. Sixty six people participated in focus groups, including farmers, representatives of food processor and retail organisations, consumer organisations, schools, public health

institutes,, non governmental organisations (NGOs), national and regional development agencies, and officials from several government ministries. These included the Ministries of Agriculture, Economic Development, Education, Tourism, Health and a representative of the president of Slovenia. The full list of individuals is included in the complete HIA report prepared for the Ministry of Health and is not replicated here <sup>138</sup>.

The workshops consisted of two elements. At the beginning, there were several short presentations in Slovenian to give the participants background information on both the HIA process and agricultural policy in Slovenia. These included presentations on the aims and methods of the HIA, including an introduction to the wide range of health determinants that should be considered in a HIA<sup>54</sup>; a general outline of the CAP and the process of accession to the EU; a specific presentation on how the Ministry of Agriculture saw development of the agricultural sector in the future; and an introduction to the organisation of the participatory group work, which had been organised around focus groups.

Each focus group had between 4-8 participants. Participants were randomly allocated to a group to ensure that a diverse mix of professional groups and lay people communicated with each other. The purpose of the group process was both to ascertain their individual levels of knowledge and to allow them to explore different facets of the policies through a process of interaction.

The focus group materials had been developed in English by the candidate and translated into Slovenian. The group work was conducted in Slovenian and facilitated by public health professionals from the National Institute of Public Health, Ljubljana who were experienced in running community-based focus groups. A note-taker (from the National Institute of Public Health) recorded the discussion by each group.

The participants were asked to identify potential positive and negative health impacts of agricultural policies that had been identified as potentially important by the Ministry of Agriculture and in the HIA steering group. This was achieved by using participatory rapid appraisal techniques <sup>112</sup> which were based on a semi-structured assessment framework. This grid prompted participants to consider key agricultural policy issues and identify potential health impacts using the main determinants of health in the form of a grid. As part of this process, participants were asked to identify which population groups would be most affected by developments in each policy area. The groups

discussed issues that were set out in the grid but also many subjects arose from the group interaction. The English version of the blank grid framework is shown in Table 10-2.

**Table 10-2     Blank HIA assessment grid used in the participatory workshops**

<b>Agricultural policy issue after EU accession</b>	<b>Potential impact on health; positive and negative effects on health determinants</b>	<b>Specific health effect (s)</b>	<b>Population at risk</b>	<b>Probability of impact occurring</b>	<b>Comments on possible size of health impacts</b>
Specific food commodity production: fruit and vegetables, dairy, meat, grain					
Wine distillation					
Changes to farm size					
Changes to rural livelihoods and communities					
Effects on the environment					

**Identification of main health impacts**

The qualitative information gained from each group was translated into English to enable a content analysis to be undertaken <sup>538</sup>. The primary focus of the analysis was to capture and then interpret the themes raised by the groups, based on the substantive meaning of the data rather than focusing on the narrative or interaction of the group process. Data reduction was carried out by creating thematic summaries of the group notes. Data were labelled and categorised in order to conduct a cross-sectional analysis across all groups. This approach was felt to offer a more systematic overview of the scope of the data.

The analytical approach allowed construction of a picture of the main positive and negative health impacts considered by the groups to be important, including areas of speculation and disagreement. The main themes identified are given in Table 10-3.

**Table 10-3     Key agricultural policy issues in Slovenia after EU**

Food and nutrition issues	Increased food imports and impact on exports; effects on diet and livelihoods. Key commodities for local farmers include dairy, wine, fruit and vegetables, grain
	Changes in nutritional value of food and food safety (negative and positive)
Environmental issues	Environmental issues: e.g. intensification of farming, pesticides
	Potential benefits of increase in organic and environmentally-friendly production
Socio-economic issues	Decrease in number of small family farms
	Barriers to small and medium sized agriculture-related enterprises/ markets
	Loss of income, employment and social capital in rural communities
	Capacity of local services (employment, education, health & social welfare) to adapt to any socio-economic changes post-accession
Other health issues	Occupational health of agricultural and food processing workers

Source: Outcomes of stakeholder HIA workshops, Slovenia 2002

**Appraisal of health impacts**

The next step in the HIA was to conduct an appraisal of health impacts. This appraisal was designed by combining the information on potential health impacts gained from the stakeholder groups with evidence from other sources in order to clarify the strength of the evidence to support or refute the ‘hypotheses’ of health impacts proposed. For example, one theme from the workshops was the hypothesis that adoption of the CAP would create larger farm sizes and intensified production methods, leading to loss of small family farms, increased rural unemployment and a consequent increase in ill-health including depression. This was anticipated to be most acute in regions that already had high rates of alcohol-related deaths and suicide. The next stage was to determine whether evidence supported an association between adopting the CAP and the loss of small family farms, or an association between farm intensification and increased rural unemployment, as well as evidence that either of these effects is linked to increased rates of ill-health.

Another theme related to fruit and vegetable production was that joining the EU would lead to increased fruit imports and reduced exports. Fruits are an important seasonal crop in Slovenia and many small farmers depend on them as a source of income. There was concern that there would be an increase in cheap imports and that closure of local

village produce markets linked to the growth of supermarkets would mean that there would no longer be a retail outlet for their produce. There was also a concern that EU accession would negatively impact on the price for consumers. The next stage was to clarify if there was any evidence to support a putative link between the introduction of the CAP and changes in fruit marketing, imports and price.

This stage of the HIA at which the evidence of health impacts was appraised essentially involved two methods; literature reviews and secondary data analysis of Slovenian health and other indicators.

To plan the evidence review, the project working group met to assess the strength of the evidence available that might link the policy issues identified in the workshops with health determinants and health outcomes. Unsurprisingly, for several key areas the evidence was found to be patchy or not available in an up to date, easily synthesisable form that was directly relevant to the policy context. In order for the HIA to proceed, the next stage was to map in more detail the evidence-base on how agriculture and food policies affect health. It was felt that there was a need for more detailed evidence reviews concerning certain agriculturally-related health determinants and health outcomes that had emerged as key concerns in the stakeholder workshops. The subjects of the reviews were wide ranging and included: Impacts of food production and supply including commodity price, quality and availability on dietary consumption and nutrition, health effects of environmentally friendly and organic farming methods, psycho-social and mental health issues in rural communities, socio-economic factors affecting health in rural areas, and occupational health impacts for agricultural workers in Slovenia. As the conduct of the reviews was beyond the scope and resources of the HIA project group, they were financed and commissioned by the WHO European Office for the Environment (based in Rome) from a range of European authors. These reviews were never intended to be comprehensive systematic reviews, due to the limitations of this methodology in relation to the subject matter, and the time constraints of the HIA. Unfortunately, although the topics and scope of the reviews were agreed by the HIA steering committee, the outputs varied considerably in scope and depth of analysis. This reflected a lack of time and financial resources for the HIA available to the project steering group, and the fact that the process was managed by the WHO separately from the HIA steering group. The actual literature reviews produced can be found in the Slovenian HIA reports <sup>535</sup>. However, only the review on organic



farming methods was sufficiently detailed to add significantly to the body of literature already available to the project. Previous published literature reviews, and reviews produced from other sources that became available during the HIA were used. This included one produced on the effectiveness of interventions, programmes and policies on increasing fruit and vegetable consumption produced by myself and colleagues in 2003 for the WHO fruit and vegetable promotion initiative <sup>539</sup>.

The data required for the health, social, environmental and economic indicators in Slovenia were agreed in consultation with the working group and are outlined in Table 10-4. The indicators were chosen because they were available from routine Slovenian data sets, and can be related to determinants of health. They are used in the HIA as measures of intermediate health outcomes. The data were collected by members of the National and Regional Institutes of Public Health in Slovenia. The list of people who assisted in the data collection is given in appendix of the final report <sup>528</sup>.

**Table 10-4    Categories of indicators collected in Slovenia at National (and regional level where available)**

Main Issue	Indicator (s)	Factors by which indicators considered
Food production and availability	Levels of food production Levels of import Levels of export: Price	Livestock: Beef Dairy products (Milk/butter ) Maize Vegetables Fruit Grapes / wine Grain (wheat / barley) Sugar beet
Farming methods	Number and size of farms by region Type of production by farm Environmentally- friendly or organic methods	Commodity grown
Effects on the environment	Use of pastures vs arable land Water table Water quality	Use of pesticides Use of (artificial) fertilizers Use of antibiotics
Working and Living Conditions for those in the Food and Agriculture Industry	Farms  People on farms	Average income by type of farm Amount of subsidies (by type of farm) Ownership (by type of farm) Levels of mechanization Numbers living on farm Nature of those working on farms: Owners, farm workers, family members Demographics of rural population Rates of occupational injury Average income by age, sex, educational level and job
Food processing	Number, ownership, size and production Food safety rates	Slaughter houses Dairies Wine producers Fruit manufacture Canned vegetables
Socio -economic factors and employment		Unemployment by region, age, sex, educational level and job Levels of relative poverty (e.g. % Households below average income, % dependent on own food production) Percentage living on farms/ rural area versus urban areas (and rate of urbanization)
Food availability and patterns of food consumption	Marketing and distribution Food consumption patterns	Numbers of food markets by type and area of distribution (eg urban versus rural areas) Provenance of foods on sale (Domestic production/import) Changes in supply and price of fruit, vegetables, meat, milk and diary products, bread over time Food consumption patterns; amount of food grown for home consumption

## **Formation of recommendations**

The information gained from the participatory appraisal, literature reviews and collection of local indicator data was appraised for each agricultural policy that had been identified for inclusion in the HIA at the screening stage. Within each policy area, the steering group prioritised likely health impacts by considering outcomes deemed to be sensitive to change according to the “best” and “worst” case policy scenarios under consideration, and which were likely to be most likely to lead to changes in health determinants, which in turn might produce potentially important health impacts. The “worst case” considered the likely impacts of adoption of the EU CAP in the absence of effective policies or structures to optimize their implementation in Slovenia. The “best case” considered the effects of the same EU policies, but in the presence of effective legislation or structures to optimize their implementation in Slovenia. These were then used to form the basis of recommendations for the Government of Slovenia. As in many HIAs, the uncertainty of the extent and nature of policy change after accession meant that, for many indicators, it was not possible to quantify the health outcomes precisely and could only predict the direction of the likely effect. Hence, the recommendations were made on the basis of group consensus of the information available to the Steering Group in 2003.

## ***Reporting the HIA findings to influence policy formation***

The final HIA report was presented to the Intergovernmental Committee on Health at the launch of the Slovenian National Food and Nutrition Action Plan in November 2003. This report presented recommendations for the government of Slovenia on a range of agricultural policy areas, including the fruit and vegetable, grain, and dairy sectors, and rural development funding<sup>528</sup>.

This chapter has discussed why a HIA was proposed in Slovenia, and the methods that were used. The HIA considered a wide range of health effects of agricultural and food policy but the next chapters will only present in detail the results related to fruit and vegetable policy.

## **Chapter 11 Results of the Health Impact Assessment in Slovenia: fruit and vegetable policy**

The methods used to undertake the health impact assessment (HIA) in the Republic of Slovenia have been described in the previous chapter. This chapter presents and discusses the results of the HIA. Although the potential health effects of four agricultural policy sectors were considered in the full HIA, only the analysis of the fruit and vegetable sector is discussed in detail because it is the focus of this thesis. The full report, which I wrote, including results and conclusions for the other agricultural sectors in more detail was presented to the Slovenian Parliament in November 2003 <sup>528</sup>.

In this chapter, the impact of the EU Community Market Organisation for the fruit and vegetable sector will be discussed before presenting the potential impacts of this for Slovenian agricultural and public health policy after accession as assessed by the HIA.

### ***Introduction: How does the EU Common Agricultural Policy impact on dietary change and public health?***

Agriculture policies can have profound effects on food consumption patterns because they create incentives for the production of some foods by providing market support and, correspondingly, disincentives from those not supported. Together, OECD countries provide almost US\$1 billion a day in agriculture subsidies<sup>540</sup>. This is paradoxical considering the huge food surpluses characterising the agricultural sector in developed countries today. Another paradox is that subsidising agriculture makes food more expensive for consumers due to loss of efficiency in production <sup>541</sup>, which in itself is likely to have effects on consumption, particularly for low-income consumers <sup>542</sup>. Traditionally, the most heavily subsidised EU agricultural sectors are cereals, beef, olive oil and milk <sup>58</sup>. Yet even commodities like tobacco, wine and sugar are receiving substantial economic support for production, which demonstrates the absence of public health considerations from EU agricultural policy making. A substantial share of the food surpluses are exported with subsidies, making EU agricultural policy a major distorting factor on worldwide markets, usually to the detriment of developing countries. The rest finds its way into the European food chain, usually as subsidised ingredients for processed foods, thereby contributing to the obesity crisis seen today <sup>74</sup>. The following section gives an overview of how the EU CAP functions in the fruit and vegetable sector to affect price and availability.

## ***The European Union Common Market Organisation for Fruit and Vegetables***

### **The fruit and vegetable market in the EU**

The European Union produces about 10% of the world's total production of fruit and vegetables, accounting for 16% of the total value of agricultural production in the EU<sup>58</sup>. The relative importance of the fruit and vegetable sector varies from country to country. Demand and production of vegetables and fruits in the EU have been stable for several years. The EU is the world's largest importer of fruit and vegetables, and the second largest exporter. The fruit and vegetable sector uses about 4% of the European Agricultural (EAGGF) budget. There is a trend towards intensification of farms, resulting in fewer and larger production units. The fruit and vegetable sector is labour intensive, with the net value per hectare being much higher than the equivalent figure for agriculture as a whole<sup>543</sup>.

### **The common market organisation for fruit and vegetables**

The fruit and vegetable sector receives the least EU financial support, relative to its market value, of all agricultural commodities. The type of support available for fruit and vegetables does not provide significant production incentives, as in the dairy and sugar sectors, but includes policy instruments which aim to protect the incomes of EU producers, which are discussed below. It could be argued that, in health terms, this sector is the only one that should justify production incentives, because fruit and vegetables are undersupplied on the European market relative to dietary recommendations leading to current low levels of consumption<sup>77</sup>.

Between 1984 and 1992, a range of EU agricultural policy instruments was introduced, including quotas, set aside policy and price support mechanisms, all designed to bring a halt to the continuing increases in agricultural production within Europe and control EU expenditure on agriculture. A major impact of these policies, relating to fruit and vegetables, has been to reduce market supply through withdrawal of produce from the market. Produce is withdrawn and is subsequently destroyed as a means of maintaining prices for producers during times of seasonal overproduction. However, in response to widespread criticism of this policy, producers' organizations have advocated alternatives, such as converting fruit into processed foods or industrial alcohol. A major policy reform of the fruit and vegetable sector, in 1996, sought to transfer responsibility to producers to tackle the continuing over-production, again involving withdrawal of

produce from the market. At present there are three European Council regulations that relate to this sector: 2200/96 concerning fresh fruit and vegetables, 2201/ 96 concerning processed fruit and vegetables, and 2202/96 which deals with special support for citrus fruits. A further amendment was adopted in 2000 (2699/2000) to address the failure of production to remain within limits for citrus fruits, tomatoes, peaches and pears. These regulations contain several measures to reduce excess production, including the introduction of marketing standards on produce quality, financing of producer organisations, intervention arrangements, withdrawal of excess produce and intervention threshold payments. The main issues that arise are outlined in the following sections.

### **Role of producer organisations in production**

The EU has provided financial support to enable the formation of organisations of fruit and vegetable producers in its Member States. Prior to the 2004 enlargement, over 1,400 producer organisations were responsible for about 40% of all fruit and vegetables produced in the EU <sup>58</sup>. The organisations are designed to give technical support to their members in order to improve product quality, to enable more effective promotion of sales through concentration of marketing, and to decrease withdrawals by ensuring that production levels are planned and production is adjusted to the level of demand. Producer organisations have considerable power over national supply. Money received from the European Community is paid into an operational fund which can fund various programmes including withdrawal compensation.

### **Intervention arrangements and withdrawals**

Several mechanisms exist through which the EU can intervene in the agricultural market to effect quantity of production and price. For fruit and vegetables, the two mechanisms used are withdrawal of produce from the market and import tariffs. These measures have the effect of artificially maintaining prices above the world market rate and thus ensuring a predictable income for farmers, one of the objectives of the CAP.

Under the 1996 regulation, the producer organisations can withdraw any of the products they wish, financed directly from the EU or via their own funds. For 16 products (lemons, satsumas, clementines, mandarins, oranges, watermelons, melons, aubergines, pears, peaches, apricots, grapes, apples, tomatoes, cauliflower) producer organisation members benefit from withdrawal compensation up to set withdrawal

ceilings (which are set as a percent of total production). No intervention buying will take place above these withdrawal ceilings. Other products can be withdrawn and compensated following a decision by producer organisations.

This previous reform of the fruit and vegetable sector aimed to give more responsibility to producers to handle and distribute withdrawn produce and to lower levels of withdrawal support payments<sup>58</sup>. This has been effective, as across the EU the amount of fruit and vegetables withdrawn with EU financial support has been reduced. From 1993- 1996 the withdrawal quantity halved and was expected to reach the lowest level in the market year 2002/2003 when the withdrawal ceilings had reached their lowest levels<sup>58</sup>. However in 2001, 1.1 million tonnes (approx 1.3%) of total production was still withdrawn at a cost of €117 million.

The 1996 reforms introduced 2 ways to reduce withdrawals:

- reduction in quantities that receive withdrawal compensation;
- a successive decrease in the withdrawal compensation paid.

Both have the effect of limiting total possible withdrawal payments to producers in any one year. Another method available was giving money, known as ‘grubbing up aid’ for removing orchards (applied mainly to apples, peaches, and nectarines). This was seen as a more permanent way of reducing excess production.

### **The use of surplus produce**

The EU regulation states that withdrawn produce should only be used for certain purposes and this must not affect the market. Products can be used for human consumption through free distribution via charities, or become processed, disposed of as animal feed, or distilled for alcohol. The regulation states that destruction must be avoided ‘wherever possible’ but as a last choice excess fruit and vegetables can be composted. It is currently up to producer organisations to decide what should be done with withdrawn produce. Currently in the EU up to 80% of this withdrawn produce is destroyed. A Swedish report on public health<sup>58</sup> has called for withdrawals to be suspended and all produce be marketed at a lower price with no withdrawal thresholds. It is suggested that lower prices would stimulate purchase and consumption of fresh produce by low-income households, who generally have the lowest intake of fruit and vegetables and are more price-sensitive.

## **Trade tariffs**

Another measure to protect the EU market is use of import tariffs. All the products included in the common market organisation for fruit and vegetables are subjected to import duty in order to prevent the import of produce at lower prices than in the EU. The entry price is set for each product reflecting the price level on the EU market and considering price variations by season. Export subsidies for EU produce can also be applied for. Tariffs vary widely from 10 to 140 percent of the border price, depending on the product and the season.

## **Single Farm Payments**

The 2003 Mid Term CAP reforms actually created a disincentive to grow fruit and vegetables. Reflecting pressure to reduce over-production, the reforms introduced a single farm payment for producers of cereals, beef and several other commodities. The farm payments were 'decoupled' from actual production levels, and are now based on historical production levels. These guaranteed farm payments allow farmers to diversify, change the type of crop grown or not to grow anything at all (under environmental regulations) without loss of subsidies, and hence income. However, fruit and vegetable growing was excluded. This means that farmers wishing to switch their land use to growing fruit and vegetables will be penalised (compared to other farmers), as they will not be entitled to receive the new single payment. The only exception to this is new Member States that have an exemption until 2008.

## **Future reforms**

The fresh and processed fruit and vegetable sectors are due for further reform in 2006. A proposal entitled 'simplification of the CMO in fruit and vegetables' was initially put forward in 2004 and a report from the Commission on the proposals to the Council and the Parliament was published in August 2004<sup>544</sup>. The strategic questions raised in the report contain little or no relevance to public health. The focus is on simplifying the CMO in order to make it more market oriented. The only health issues that have been put forward are not new and focus solely on stimulating demand-side activities, specifically the need for 'promoting consumption of fruit and vegetables', although they 'invite the commission to introduce a school fruit scheme to reach young people'. On 22<sup>nd</sup> November 2004 the Dutch Presidency adopted the conclusions of this report<sup>545</sup>. During 2006, the Commission will develop and present legislative proposals, for presentation to the European Parliament in autumn 2006.



## ***Agricultural Policy in Slovenia during accession***

The initial phase of the HIA was to assess the impact of accession, and incorporating the CAP into Slovenian National Policy. This section briefly discusses the findings of this policy analysis for a range of agricultural issues before focusing on the fruit and vegetable sector.

### **Accession negotiations**

The process of accession required each candidate country to harmonise their legal system with EU law and adjust national policies and institutions. Accession negotiations were formally opened with Slovenia in March 1998, with those on the agricultural chapter opened in June 2000. There were 3 parts of the accession process for candidate countries:

- Implementing the *acquis* into national law;
- Requests for derogations from the *acquis*;
- Agreeing the financial framework.

The agricultural negotiations took 5 years. The final financial package for adoption of the CAP (including levels of direct payments, quotas and rural development funds) was agreed in late 2002, after the HIA had commenced. At the Copenhagen summit (December 2002) EU leaders reached agreement with ministers from the 10 candidate countries on the terms of their EU entry, which was to take place on May 1<sup>st</sup> 2004. Under the agreement, funding available for all candidate countries is fixed at €5.1 billion for 2004-2006 and EU direct farmer aid will be phased in over 10 years. Farmers in the new Member States in theory receive 55% of the direct support levels of the former EU-15 in year 1, rising to 100% incrementally by 2010. This requires each accession country to top up the payments made by the EU. In return, farmers from new Member States will have full and immediate access to CAP market measures, such as export refunds.

The total financial inflow into Slovenia for agriculture after accession was expected to be approximately €80 per citizen. This is the maximum allocation (per capita) in any of the new Member States but is well below the agricultural funding given to former EU-15 Member States (e.g. Ireland €450, Denmark €250 and France €150 per citizen).

The three main areas of contention in the negotiations for the agricultural chapter were the progressive introduction of EU funded direct payments to farmers (leaving new Member States at a disadvantage to the former EU-15 for up to 10 years), production quotas which were lower than current national production levels and limits to rural development approaches (a particular issue in Slovenia with its large number of small scale farmers).

### **Fruit and vegetable production in Slovenia before accession**

In Slovenia, fruit and vegetable production accounts for about 5% of the value of the agricultural sector (compared with 4% of the EU CAP budget). Slovenia ranks among the smallest producers in Europe, with less than 3000 hectares devoted to fruit and vegetable growing. In comparison the largest European horticultural producers are the Mediterranean countries (Italy, Spain and France), the Netherlands, with Poland and Hungary being important vegetable producers among the EU accession countries.

In 2000 the Statistical Office for the Republic of Slovenia conducted a horticultural census in Slovenia, in cooperation with the Agricultural Advisory Service <sup>529</sup>. This collected data from all market producers. Changes in methodology mean that data on horticultural production from previous years are not compatible with this census, so that only data on 2000 and 2001 production was available for use in the HIA.

The agricultural census showed that there are a large number of small scale fruit and vegetable farmers in Slovenia. In 2001, 2109 separate producers cultivated 2,258 hectares of vegetables. On average each farmer only has 0.8 Ha of horticultural land; 53% of farms are 1 ha or less, and only 57 (less than 2.5%) have more than 5 Ha of land. <sup>529</sup>. The main crops are shown in Table 11-1.

Between 2000 and 2001, the growing area for vegetables increased across Slovenia. Weather conditions have a considerable influence on the yield, and explain why, from 2000 to 2001, the yield fell by one quarter, despite a larger growing area. (table 11-1).

Vegetable production in Slovenia brings a relatively high income per area unit in Slovenia compared with other crops, such as cereals <sup>529</sup>. The share of crops intended for sale varies significantly for individual vegetable producers. Up to 40% of vegetables produced in Slovenia are for family consumption, which is not directly affected by agricultural policy (although it may be influenced by rural development and education policies).

In Slovenia, vegetable production is much more dispersed than in other EU countries. There are two reasons for this; firstly, in the EU, vegetables are cultivated on approximately 10% of all rural holdings; compared to almost 80% of farms in Slovenia. Secondly, the share of farms focusing primarily on vegetable production is also five times less in Slovenia than in the EU. Also farmers that cultivate vegetables often grow several different types, so they are unable to offer an adequate amount of vegetables to supply a market on a regular basis.

**Table 11-1: Changes in vegetable production between 2000-2001 in Slovenia**

Product	Arable land (ha)		Crops (t)	
	2000	2001	2000	2001
Vegetables total	3.242	3.531	78.809	61.168
Cabbage	748	736	26.993	17.152
Lettuce	318	357	6.894	5.268
Onion	259	291	6.260	5.430
Beans	224	315	2.103	3.076
Paprika	204	212	5.824	4.617
Tomato	162	190	3.421	3.144
Cucumber	152	195	3.002	3.170
Chicory	149	172	2.386	2.247
Red beet	123	137	3.141	2.493
Cauliflower and broccoli	85	81	1.474	1.549
Others	818	845	17.311	13.022

Source: Statistical office of the Republic of Slovenia<sup>529</sup>

### Summary

This chapter has discussed the organisation of the CAP fruit and vegetable sector, and its implications for both producers and consumers in the European Union. It is clear from the horticultural census that there are a large number of small scale producers of many products, including fruit and vegetables in Slovenia. Many of the producers sell less than 60% of their produce, and derive little income from their production, with much going to home consumption. In the past, family farming in Slovenia has been seen as a ‘part-time employment’ but currently unemployment is rising and is now higher in rural areas (chapter 10). The full economic implications of the CAP for small farmers following accession is still unclear. The CAP aims to increase productivity through intensification and technology, and to limit levels of national production through quotas, often resulting in financial disincentives for maintaining smaller farm units. This could lead, in the medium to long term, to increased unemployment of the

rural poor in the agricultural regions <sup>528</sup>, and reduced local production of food. The following chapter focuses on the specific implications of CAP adoption for both Slovenian producers and population health.

## **Chapter 12 Implications of EU accession for Slovenian fruit and vegetable policy and population health**

### ***Post-accession changes in agriculture policy***

The policy analysis of the effects of the CAP after accession was informed by research commissioned by the HIA-steering group from the University of Ljubljana (see chapter 10)<sup>530</sup>.

Pre-accession, Slovenian Agricultural policy proposals focused on 'social and environmental' measures, balancing national food production with the need for rural development sympathetic to Slovenian farm culture and organisation (*Kuhar 2003, personal communication*). It aimed to improve production and marketing structures in both agriculture and food processing industries. Proposals for the poorer rural areas included economic diversification and improvement of rural infrastructures<sup>530</sup>. The Ministry of Agriculture saw the development of niche markets (such as organic farming particularly fruits and vegetables), and development of other 'on-farm activities' (such as agri-tourism) as important to ensure sustainable livelihoods of small rural producers. These proposals needed to recognise that the population of the rural areas in Slovenia, were older and had a lower level of educational attainment than those in urban areas (Chapter 10), and such developments would require investment in agricultural education and extension services. Although Slovenia adopted a series of decrees on rural development in 2001, covering issues such as the agri-environmental programme and compensatory payments for disadvantaged regions (in line with the CAP), EU agricultural rural development funds allocated to Slovenia were less than required to implement their full 'rural development plans'. These will be co-financed at a maximum rate of 80% by the EU. The Commission commenced bilateral discussions during 2003 to help accession countries formulate their rural development programmes. Some of the policies on economic diversification seen as important for rural producers in Slovenia, were stopped until negotiations on the application of allocated agricultural funds had been finalised (this did not happen during the time that the HIA was being undertaken).

In contrast, significant progress was made prior to accession in aligning Slovenia's legislation in various product sectors with that of the EU CAP. Progress was also made in food safety, with the establishment of competent authorities for veterinary control,

control of animal diseases, public health measures, animal waste rendering and animal nutrition. Although the new food safety strategy was specifically designed to align Slovenian policy with EU legislation and practice, it should be noted that Slovenia already had very good food safety surveillance systems in place, based on the Institutes of Public Health, and including monitoring of pesticide residues in fruits and vegetables<sup>528</sup>.

There are few derogations (nationally negotiated exceptions) allowed to the CAP. In the accession negotiations, Slovenia agreed transitional periods to allow for farms to introduce EU standards for battery cages for egg-laying hens, and derogations for milk, suckling cows and sheep yields (with quotas not to be agreed for dairy produce until 2006). A preferential trade agreement on wines and spirits was also signed between Slovenia and the EU in April 2001. A permanent derogation has been agreed for Cvicek wine PTP (a local wine produced by mixing red and white grapes). There is also agreement on wine zoning (i.e. 2 zones with special treatments have been created in one border region). The implications of some of these policy changes for public health were assessed in the full HIA<sup>528</sup>. The next section will discuss the policy implications specifically for the fruit and vegetable sector in Slovenia.

### ***The potential impact of the EU CAP on the fruit and vegetable sector in Slovenia***

It was clear that, following EU accession, significant changes to agricultural trade would occur in Slovenia, including changes to regulations and procedures previously in place for fruit and vegetables. All trade barriers (tariffs and special custom duties) protecting domestic producers from external competitive pressure were to be removed. Previous preferential trade agreements (including both limited and no trade barriers) with former Yugoslav republics were replaced with a less favourable regime covering their trading relationships with EU countries.

These changes are expected to raise prices of fruit and vegetables to those in the rest of the EU. Although this is likely to impact first to producers but its effects are also likely to be seen in consumer prices. This will mean that after accession there is likely to be an increase in the cost of some fruits and vegetables available to Slovenian consumers. This is expected to be most evident in the Slovenian-produced fruit market, where average consumer prices were below the level in the EU as a whole. It is not clear what impact these price increases will have on consumption. Fruit and vegetable intake is

less price-sensitive than other foods<sup>546</sup>. However, this does not exclude the possibility that there will be decreased consumption of certain fruits and vegetables that are common in the Slovene diet, or at least the substitution of some fruits and vegetables with less expensive varieties that may have a lower nutritional benefit.

Yet the affect of accession on fruit and vegetable prices will not be simple. Prices of some fruits may decrease, particularly citrus fruits produced in EU Member States, due to abolition of old trade regimes and removal of import tariffs. Currently Slovenia imports a wide range of fruits, including oranges, and projections suggest that imports will increase after accession <sup>530</sup>. Although this may bring benefits to consumers, it will have to be balanced against negative effects on local production of traditional fruit crops. It is likely that introduction of CAP regulations will further stimulate the existing trend towards substitution of “exotic” imported fruits (mainly oranges and bananas) for locally produced fruit (especially apples).

Clearly the EU CAP will also have an impact on Slovenian exports, through changes in subsidies and trade barriers. Prior to accession, Slovenia produced 20% more apples than required for domestic consumption, with much of the excess exported to Austria. As EU import tariffs will no longer apply, exports to the EU will be easier and cheaper. This should maintain the current trade, or even lead to an increase, with benefits to producers up to agreed production quotas.

It is unlikely that the volume of the internal Slovenian market for fruit and vegetables will change much after accession. However, patterns of trade with other countries in Europe may alter, particularly in relation to imports from former Yugoslavian countries. For example, prior to accession Slovenia had free-trade agreements with Macedonia and Bosnia, especially for varieties not produced in Slovenia, industrial fruits for juice production, melons, salad, tomatoes and some vegetables. After accession there will be higher barriers to this trade, with an increase in the cost of imports, unless the Stability Pact countries (which include the remaining countries of ex-Yugoslavia) negotiate favourable trade regimes, which is unlikely. However, it is likely that there may be changes in the countries supplying imports e.g. Greece substituting for Macedonia, partly because of the absence of tariffs but also reassurance that food safety meets EU standards.

In summary, EU accession is likely to increase price of locally produced fruits and vegetables, and decrease the price of imported fruits and other produce. Traditional supply routes for imports will also change. This is likely to have the largest impacts on Slovenian farmers growing fruit and vegetables. The impact on consumption patterns is less clear. Overall the price of a ‘standard basket’ of fruits and vegetables can be expected to increase overall, due to higher prices of Slovene produce, and this will likely lead to substitution of some products.

### **Producer Organisations**

Slovene producers and the Ministry of Agriculture support the formation of farm co-operatives to maximise increase economies of scale. A legal basis for such producer organisations has been adopted, a move seen as an important step to enhanced productivity in the fruit and vegetable sector after accession. It is not, however, clear how easy it will be for small farms if they wish to join these producer organisations, for example whether there will be minimum production levels.

### **Withdrawal Mechanisms**

Prior to accession in Slovenia there was no policy of price thresholds or withdrawing produce from the market during seasonal over production. These direct interventions in the market had not been considered relevant for agricultural production or protection of farmer incomes. Domestically produced fruit is of high quality and Slovenia traditionally imports “industrial” apples and other fruits of lower quality for processing (at a quality that is usually designated for withdrawal within the EU). The use of direct farm payments, including withdrawal mechanisms, is still one of the major elements of the CAP (accounting for up to 80% of the budget). Withdrawal mechanisms are likely to come into effect in Slovenia for certain fruits and vegetables, such as apples, which will further increase the price of fruit and vegetables for consumers.

## ***Dietary intake in Slovenia***

### **Current population nutritional status**

Population health concerns in Slovenia include high rates of cardiovascular disease and cancers (chapter 10). The HIA examined potential dietary explanations for these high rates of morbidity and mortality. Over 50% of the adult Slovenian population are overweight or obese (tables 12-1 and 12-2). Levels of obesity are higher for men than women. However this is also a growing problem in children as 15% of 6-7 year olds



and 11 % of 7-15 year olds are also overweight (although these rates are lower than in many EU countries including the UK). Among the three regions that were the focus of the HIA, rates of obesity are highest in the agricultural region of Promurje (Table 12-2).

**Table 12-1    Nutritional status of different population groups in Slovenia, low body weight and overweight with obesity, both sexes**

Age range	Sample size	Persons (%) with low body weight BMI < 18,5	Persons (%) overweight or obese BMI > 25	Author and year of research
6 - 7	1685	-	15.2*	Bigec, Primary health Centre Maribor, 1998
7 – 15	3068	6.4	11.4	Radisavljevic et all, 1992
18 – 19	296	9.8	12.4	Gabrijelcic, IVZ 2001
15 – 20	1330	9.2	12.6	Valic S. et all, ZZV N. Gorica, 2000
25 – 64	1692	1.4	63.4	CINDI Ljubljana 1990/91
25 – 64	1342	1.3	62.2	CINDI Ljubljana 1996/97
25 – 64	9034	1.3	54.6	CINDI Health Monitor 2001
18 – 65	2183	7.3 ( BMI < 20)	45.25	Koch, 1997
Over 18	1007	4.4	48.1	IVZ - SJM, 1999
60 – 101	1614	0.9	62.9	Pokorn, 1991

Sources: various studies, listed in the last column of the table

**Table 12-2    Body mass index of the adult population in Slovenia (25 – 65 years old) and three specific regions with three different kinds of diets**

Body mass index	Slovenia			South Primorska	Gorenjska	Promurje
	male	female	total	total	Total	total
18.49 and lower	0.3	2.1	1.3	2.3	1.4	1.2
18.50 – 24.99	33.2	53.3	44.1	46.1	45.2	39.9
25.00 – 29.99	50.0	30.9	39.6	37.2	40.7	40.2
30.00 and more	16.5	13.8	15.0	14.5	12.7	18.8

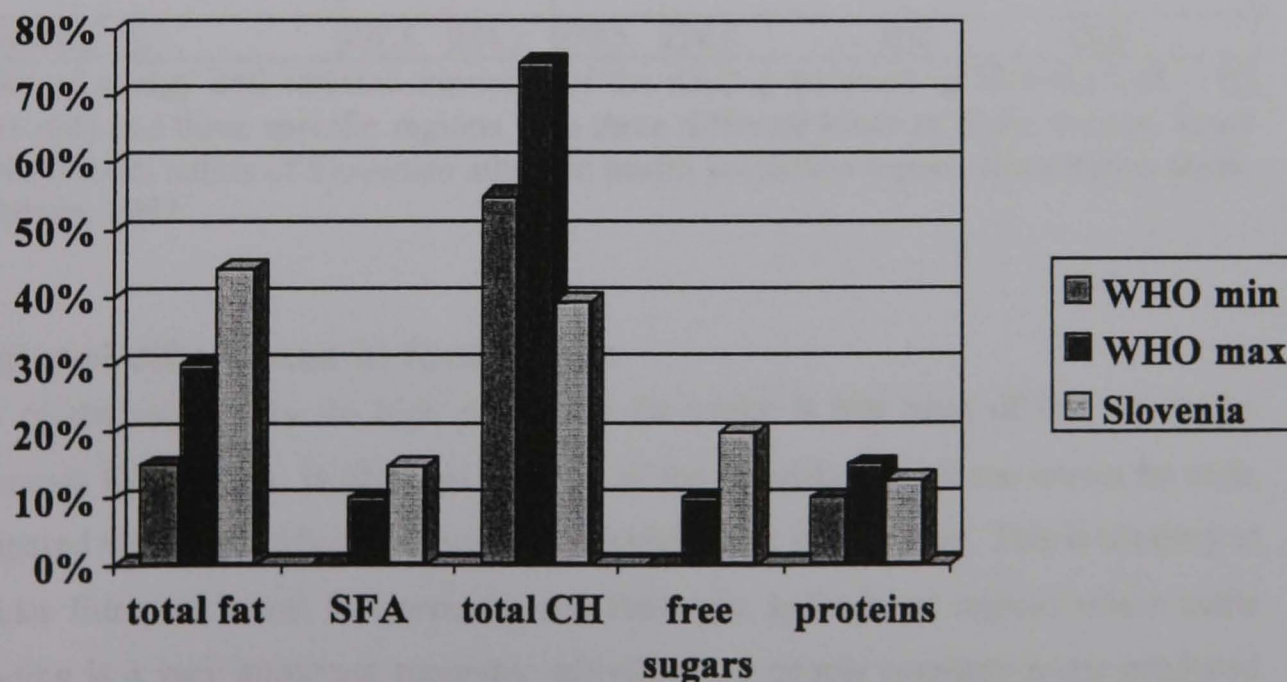
(Gorenjska – mid European diet, comparable with Austria, north Italy, south Germany), Promurje (Panonian diet, comparable with Hungary), South Primorska (Mediterranean diet, comparable with Croatia, Greece, south Italy),  
Source: CINDI HM data 2001

## Dietary patterns

The cause of the worrying trend in increasing obesity can be understood by looking at dietary patterns in Slovenia. The most recent CINDI data available showed that the worst dietary patterns and habits are among men, those in lower socio-economic groups, the unemployed, those with low educational status, 25-35 year olds and farmers.

Individual energy intake is high in Slovenia (compared with WHO recommendations). Average daily energy intake is 11,422 kJ (2,727 kcal)/day. The main cause of this is the very high intake of total fats, saturated fats and sugars (Figure 12-1), combined with low levels of fruits and vegetables. There do not seem to be significant regional differences in fat and sugar consumption (Table 12-3). It seems likely that lowering energy intake through reduced fat intake would make a significant contribution to normalising daily energy intake in the population.

**Figure 12-1** Macro nutrient intake in Slovene adult population (18 – 65 years) in comparison with WHO recommendations,



Source: Koch, V<sup>503</sup>

**Table 12-3** Adult dietary intake in Slovenia in 3 regions <sup>503</sup>

	Slovenia			South Primorska	Gorenjska	Promurje
	male	female	total	total	Total	total
Daily energy intake (kJ)	12114	10731	11422	9997	12091	11464
Selected nutrients. daily intake in grams and % of daily energy intake						
Proteins (g)	92.7	81.8	87.3	81	87.9	82.2
Proteins (%)	12.8	12.7	12.8	13.6	12.2	12
Total carbohydrates (g)	296.7	273.4	285.1	261.1	288.3	318.2
Total carbohydrates (%)	38.5	40	39.3	41.1	37.4	43.7
Sugars (g)	148.3	139.1	143.7	133.2	145.1	162.8
Sugars (%)	19.2	20.4	19.8	21	18.8	22.3
Dietary fibres (g)	20.3	19.9	20.1	20	18.8	25
Total fats (g)	140.6	127.9	134.3	110.1	152.4	123.9
Total fats (%)	43.7	44.9	44.3	41.6	47.5	40.8
Saturated fatty acids (g)	47	42.7	44.9	36.1	50.7	41.4
Saturated fatty acids (%)	14.6	15	14.8	13.7	15.8	13.6
Mono unsaturated fatty acids (g)	41.8	37	39.4	32.5	44.9	35.8
Mono unsaturated fatty acids (%)	12.9	13	13	12.3	14	11.7
Poly unsaturated fatty acids (g)	12.5	10.9	11.7	9	13.1	12.5
Poli unsaturated fatty acids (%)	3.9	3.8	3.85	3.4	4.1	4.1
Cholesterol (g)	292.8	264.2	278.5	224.6	313	253

Intake of energy and selected nutrients of the adult population in Slovenia (18 – 65 years old) and three specific regions with three different kinds of diets: Source: Koch V. Nutritional habits of Slovenian adults in health protection aspect, Dissertation thesis, Ljubljana, 1997.

**Regional differences in food intake**

One of the reasons for the high population fat intake is that most of the population consumes full fat milk. In Slovenia only 4% of the population drink the lowest fat milk, compared with over 20% of the population which drink full fat milk. This is contrary to a wider European trend. In Gorenjska and Promurje, agricultural regions where cattle breeding is a very important economic activity, more people consume home produced full fat milk. However, there are other dietary issues relating to animal production including a high intake of red meat. Although plant oils are the most popular product for cooking, over 12% of the population still use animal lard, with one third of the population in Promurje region mostly using lard in cooking.

This compares with a low dietary intake of fruit and vegetables in the population. Less than half of Slovenians consume fruits on daily basis, and just over 50% consume vegetables daily. The main regional differences in diet are that in Pomurje region, people consume more red meat, eggs, and fried foods, while consuming less fruits.

**Table 12-4** Intake of selected foods in the Slovenian adult population (25 – 65 years old) in three regions

Intake of selected food groups	Slovenia			South Primorska	Gorenjska	Pomurje
	male	female	total	total	Total	total
Fruits and vegetables, intake more than once a day						
Fruits (fresh and cooked)	20.5	38.1	30.1	36.4	31.9	27.7
Vegetables (fresh/cooked)	18.2	25.1	21.9	26.5	17.6	28.5
Selected food groups, intake once a day and more						
Fruits (fresh and cooked)	44.8	67.1	57.0	62.5	59.6	54.3
Vegetables (fresh/cooked)	63.0	73.0	68.4	71.8	67.1	70.4
Milk and dairy products	52.5	64.5	59.0	71.2	60.7	52.7
Selected food groups, intake more than four times/week						
Red meat	22.2	11.6	16.5	18.2	11.9	23.3
Poultry	11.8	11.3	11.4	10.0	9.7	17.0
Selected food groups, intake once/week and more						
Fish, fish products, sea fruits	29.8	29.2	29.4	43.8	27.3	33.3
Egg as main food in the meal	40.2	32.9	36.2	34.0	34.3	43.3
Selected processed foods,						
Fried foods, 4x/week and more	5.8	2.9	4.2	5.2	2.1	11.0
Fried foods, 1x/week and more	49.9	36.4	42.5	44.9	34.3	63.0
Soft drinks, intake on daily basis	34.7	26.8	30.4	29.6	26.8	42.9

Source: CINDI HM data 2001

### ***The impact of CAP on fruit and vegetable consumption in Slovenia***

#### **The impact of current low fruit and vegetable intake in Slovenia**

The recommended dietary intake of fresh fruits and vegetables is 400g per person per day (excluding potatoes) <sup>266</sup>. In Slovenia, a recent (but not nationally representative) dietary survey estimated that the average fruit and vegetable consumption is only 304g per person per day <sup>503</sup>. This compares with an estimated intake of 359 g per person per day from Slovenian food availability statistics (chapter 8), which is likely to overestimate actual consumption (see chapter 3 for discussion). More details about the sources of data on fruit and vegetable intake available in Slovenia are discussed in

Chapter 8. However, it is clear that survey estimates show that consumption is between 50-100g per day (or approximately 1 standard serving) lower than the minimum intake recommended.

It was estimated for this thesis that if consumption in Slovenia was increased to 600g/day (approximating to average consumption of countries such as Greece), the current disease burden for heart disease could be reduced by 19%, stroke by 12% and various cancers between 2-13 % in Slovenia (Chapter 8). Increasing consumption up to a population average of 400g/day would result in lower reductions in disease as the normal population distribution of intakes means that a large number of people would not reach 400g per person each day.

Taken together with knowledge of other dietary risk factors, such as the high rate of dietary fat consumption and high meat consumption, together with increasing rates of childhood and adult obesity, suggests that a range of policies is needed to tackle the determinants of unhealthy diets, and their consequences for population health in Slovenia.

### **What are the trends in fruit and vegetable demand?**

What types of fruit and vegetable products are people consuming in Slovenia and what are the trends in consumption? There are no surveys that can provide data on trends in consumption of specific products in Slovenia. It is possible to obtain data on trends of production, import and export, from which it is possible to infer something about population intake. Recent horticultural statistics indicate increasing imports of bananas, kiwi and oranges, mostly from outside the EU <sup>529</sup>. Market demand for apples is decreasing even though they are grown extensively in Slovenia, and relatively cheap compared to imported fruit. However, the large amount of produce grown for home consumption in Slovenia (estimated to be up to 39% for some producers in one small survey<sup>503</sup>) means that it is harder to interpret these trade statistics than in other EU countries, as much produce does not reach the market. After accession it is likely that prices will increase overall, leading to reductions in fruit and vegetable intake, although it is anticipated that this will impact on urban populations rather than the small farmers in rural areas.

## ***Interventions to increase fruit and vegetable consumption***

Although a review of literature evaluating interventions to increase fruit and vegetable consumption was planned as part of the HIA, time and resource constraints meant that this was not conducted for this project (see chapter 10) so literature reviews from other sources were used. This included a systematic review on the effectiveness of interventions, programmes and policies on increasing fruit and vegetable consumption produced by myself and colleagues for the WHO fruit and vegetable promotion initiative initially in 2003<sup>539</sup>. The full methods and results of this review are published elsewhere<sup>547 548</sup>.

The results of this subsequent systematic review showed that a wide range of interventions and programmes promoting fruit and vegetable intake in adults and children have taken place and that most interventions had positive findings in spite of the known difficulties of changing individual diet<sup>549</sup>. The largest effects were generally observed among individuals who were already at a higher risk for disease. This could reflect their increased motivation to improve their diet. In primary prevention interventions in healthy adults, fruit and vegetable intake was increased by approximately half a serving per day. Consistent positive effects were seen in studies involving face-to-face education or counselling. The slightly greater effectiveness of an individual approach would seem intuitive but this must be balanced against the high cost, time demands and need for trained staff that this approach requires. It does not seem to be a feasible whole population solution. Interventions using telephone contacts or computer-tailored information appeared to be a reasonably effective alternative. Community based multi-component interventions also achieved positive results. The results in other settings, such as worksites and supermarkets were inconclusive for adults. In children, unsurprisingly school-based approaches were most effective. Positive factors included incorporating nutrition in the curriculum, together with increased supply and parental involvement.

Unfortunately, although several national and local programmes from a variety of countries were identified, including some agricultural interventions, most evaluations did not use a control group and their findings were thus excluded from the review. There was also insufficient information to assess the cost of the dietary interventions in relation to the effects achieved. However, an Australian study estimated that the national campaigns to increase fruit and vegetable intake could prevent 3,626 disability

adjusted life years (DALYs) each year in Australia, with corresponding cost savings of approximately AUS\$125 million a year over the implementation costs (estimated at approximately AU\$2.5 million a year)<sup>550</sup>. It suggested that a national Australian campaign is likely to be cost-effective with an estimated cost of AU\$677 per DALY gained (95% confidence interval \$513, \$16,392). There is a clear need for economic evaluations of other interventions for comparison to help public health planners identify what would be best suited to a particular country's needs.

It was also clear from this comprehensive review that more research is required to better understand the factors influencing fruit and vegetable intake, including economic, social and environmental factors that influence food availability.

***Recommendations of the HIA for improving Public Health***

**Elements of a food policy to increase fruit and vegetable consumption**

It is clear from the HIA, that any policy on fruit and vegetable designed to improve health must consider both supply and demand issues. Traditionally, the public health community has focused on stimulating demand through health education campaigns. However, the CAP influences both the availability and the affordability of food, and therefore influences demand. The elements of a food policy that would take account of both demand and supply side issues is outlined in Table 12-5.



**Table 12-5** Elements of a food policy to increase fruit and vegetable consumption

	Issue	Example of Policy
Supply-Side Issues	Control of production  Price control    Availability	EU CMO for fruit and vegetables EU CMO for fruit and vegetables Retail sector policy Taxation- and other factors affecting price elasticity Supply chain Number and density of retail outlets
Demand Side Issues	Increasing demand       Preventing other harmful behaviours that may influence fruit and vegetable intake	Fruit and vegetable advertising by agriculture or retail sector Health education and information campaigns Specific projects to increase fruit and vegetable consumption e.g. schools meals Marketing of unhealthy foods to children

The aim of the Slovenian Ministry of Health is to increase consumption of fresh and frozen fruits and vegetables, as well as safeguarding the economic status of the population. International guidelines recommend that each person should consume a minimum of 400g/ per person/ per day of fruits and vegetables. This is not currently being met for all sections of society in Slovenia. Although precise data on intake of fruit and vegetables is not available, it is clear that the national consumption of fruit and vegetables should be increased to reduce the burden of disease (chapter 8). Policies should aim to increase population fruit and vegetable intake by up to 25% (100g/ per person per day). This also will create increased demand which would provide an opportunity to increase horticulture production in Slovenia.

There are some potential opportunities for collaboration between the Ministries of Health and Agriculture to work together to increase demand to achieve dietary recommendations. Such increases could be met by increased Slovenian production of fresh and frozen fruit and vegetables. This will involve determining what fruits and vegetables will be most suited to both the agricultural environment and market demand.



### **Increasing availability**

In principle, the fruit and vegetable sector is the only one that merits production incentives on grounds of public health, as fruit and vegetables are undersupplied on the European and local Slovenian market, reflected in low consumption levels in Slovenia and across the EU <sup>503 77</sup>. However, production subsidies are contrary to CAP regulations.

Another potential policy option is to redirect current production from products like grain to fruits and vegetables. There are many potential benefits from this approach, not only for health, but also in stimulating employment and income of farmers as horticulture is not only more labour intensive but produces high added value. One approach would be to encourage smaller farms to convert to horticulture production with support from rural development instruments (e.g. in Pomurje) to help maintain rural livelihoods. However, at present this is also against regulations agreed in the mid-term CAP reforms in 2003.

### **Improving multi-sectoral working to strengthen the fruit and vegetable sector**

Current national intake data cannot provide an accurate picture of the daily intake of fruit and vegetables by age and sex in the population. Nor are databases in place to monitor consumption trends over time and in different regions. Developing inter-sectoral collaboration to create comparable databases of fruit and vegetable production, local sales, consumption, and processing would facilitate targeting of marketing campaigns in way that would increase consumption. A first step would be the creation of better statistical databases, shared between the agricultural, economic, statistical and health sectors, to collect data on food production.

These databases could be the basis of well-planned joint policies to improve consumer education and provide better research for marketing to increase consumption of fruit and vegetables in Slovenia.

### **Import tariffs, withdrawals and price**

It was believed that prices would rise after accession. This was expected to have a negative impact on consumption. For example, a 10 percent increase in consumer prices due to import tariffs on produce from elsewhere in the former Yugoslavia, a plausible figure according to data from the OECD, would decrease consumption by 5

percent, assuming a price elasticity of -0.5<sup>546</sup>. This is three times as high as what would be caused by withdrawal measures. However, price thresholds and withdrawal measures are also likely to increase prices, particularly at seasonal times of overproduction. The consumption lowering effect is likely to be more pronounced for low income groups who are more price sensitive and who already have the lowest intake. In this way, the higher fruit and vegetable prices in the EU may increase health inequalities. The current EU common market organisation for fruit and vegetables is not coherent with the public health goal of increasing consumption, and it is hoped that the tariffs and withdrawal measures will be addressed in the upcoming reform of the sector due in 2006.

However, it is important that the Ministries of Health and Agriculture work together to ensure that affordable fruits and vegetables are still available, particularly to low income consumers. This may involve the use of subsidised school meals for low income families, or ensuring that 'food credits' used in welfare support can only be used to purchase 'healthy food products' such as fruits and vegetables.

If EU withdrawal compensation mechanisms are introduced after accession then this should only be at times of extreme local, seasonal overproduction. It is also recommended that any withdrawal produce should be used for human consumption (allowed by EU regulation although not common in pre-2004 Member States). The Ministry of Health could work with the Ministry of Agriculture to devise disposal schemes to enable low-income families or school children access to the withdrawn produce.

### **Improving quality**

Across Europe there is increasing concern for food safety, including monitoring of pesticide levels in foods. This is particularly true in the fruit and vegetable sector where there is a rising demand for organic produce. Although organic produce offers no significant health benefits over non-organic fruits and vegetables in the EU (due to low levels of pesticide residues), support through various 'pillar 2' CAP instruments could potentially be used to help Slovenian farmers take advantage of the market for organic fruit and vegetables. Such products can expect to achieve strong demand within the EU, improving agricultural incomes after the initial investment in farm conversion.

## **Conclusions**

Fruit and vegetable policy in the EU has been reformed but there is still considerable market distortion, with negative implications for nutrition and health through its impact on price and availability. Slovenian agriculture has a strong fruit and vegetable sector, although currently this is inefficient as it is based on a large number of small scale farms. There are obvious health benefits from promotion of fruit and vegetable production and consequent increased consumption. This would benefit the Slovene population which currently has low levels of fruit and vegetable intake and high intake of dietary fats and sugars, accompanied by rising rates of obesity and high rates of diet-related non-communicable diseases.

As far as I am aware, Slovenia is the only country that has undertaken a prospective health impact assessment of a new national agricultural policy. Although this case study relates to Slovenia, the experience and many of the recommendations are applicable to all EU countries (both pre- and post- 2004 Member States) and the European Commission. From this work it is clear that, even if governments wish to make changes in conformity with public health and nutrition recommendations, they may be unable to do so because of the European regulatory environment in agriculture.

The HIA in Slovenia was a pilot project to estimate the likely impact on health of complex food policies such as agriculture. It was acknowledged at the start that this would involve an element of methodological development and that, given the complexity of policies involved, the final analysis would not be as comprehensive as may be desired either by academics or policymakers. The HIA needed to look at both demand and supply side factors affecting fruit and vegetable intake. For several of these factors, evidence of how they impacted on health was poor or unavailable, as was evidence of the effectiveness of making changes to many parts of the pathway, even after a high quality systematic review of the literature was undertaken, because the evidence linking agricultural interventions to nutrition and health is virtually non-existent. Consequently the HIA was only to make recommendations based on the best available evidence. An important part of this process is the learning of lessons regarding the implementation of HIA. There were many constraints relating to the methods used, including lack of data, time and resources. However, the HIA proved to be a useful method for improving inter-sectoral collaboration, in this case, between ministries of health and agriculture and regional development agencies. A full

evaluation of the outcomes of the health impact assessment was beyond the scope of this thesis, as it required time to elapse between the HIA, accession to the EU and evaluating the impact of the HIA. A process evaluation is planned by the Slovenian Institute of Public Health in 2006 (M Gabrejelcic-Blenkus, pers comm). The strengths and limitations of the HIA method as a means of informing policy development are discussed in the following chapter.

# Chapter 13 The use of health impact assessment to inform the policy process

This chapter outlines the different approaches to HIA and the applications they have been put to in Europe. It then discusses the strengths and limitations of HIA, as currently used, as an evidence-based methodology to inform the policy process.

## The application of Health Impact Assessment to policy-making in European Member States

Although HIA is not a legal requirement anywhere in the EU, 12 governments recognise its potential in informing the policy development process <sup>551</sup>. Several of the 15 pre-2004 Member States (EU-15) already have considerable experience in applying HIA at local, regional and national level, including Germany, Ireland, UK, the Netherlands and Sweden. An overview of HIA applications in the EU-15 countries is given in Table 13-1. At least 8 of the 10 Member States that acceded to the EU in May 2004 had already considered the use of HIA or had experience of applying HIA or other associated approaches to inter-sectoral health improvement (Table 13-2). A variety of HIA methods have been used, all of which have the goal of assessing the impact of a policy on public health.

Table 13-1 HIA applications in former EU-15 Member States

Country	Administrative level at which HIA conducted (national, regional, local)	Policy sectors to which HIA has been applied
Netherlands	Health impact screening of national policy <sup>131</sup>	Housing policy <sup>132</sup> , employment <sup>134</sup> , , environmental energy tax <sup>131</sup> , national budget <sup>133</sup>
England	National	Burglary reduction initiative <sup>552</sup> , national alcohol strategy <sup>553</sup>
	Regional	London Mayoral strategies including transport, waste disposal, economic development <sup>137 554</sup>
	Local	Regeneration projects <sup>555</sup> , farmers markets
Wales	National <sup>553</sup>	Home energy efficiency scheme, Objective 1 programme <sup>556</sup> , Tourism (national botanical garden) <sup>556</sup>
	Local	Power station development, landfill sites, housing renewal scheme
Sweden	National	Agriculture <sup>57</sup> , Alcohol policy
	Local county council level <sup>553</sup>	Various

Sources: Welsh Assembly Government (2003), Health Development Agency HIA gateway website (<http://www.hiagateway.org.uk/>).

The eight ex-communist new Member States (the other new Member States are Malta and Cyprus) have some tradition of assessing health impacts of other policies. For example, in 1966 the public hygiene service in the former Czechoslovakia was given legal powers to assess health impacts, although in practice it had little influence on decisions <sup>557</sup>. However, this formal ‘environmental health’ role was narrow, focusing on adherence to technical standards. It contrasts with the emergence of broader public health approaches, creating a legacy of ambiguity about the concept of HIA.

Many of the new Member States that joined in 2004 are developing more broadly-based models of HIA, adopting multi-sectoral approaches to public health. For example, a Hungarian study exploring opportunities and barriers to using HIA to inform inter-sectoral policy <sup>558</sup> initiated a process of HIA development by the Ministry of Health <sup>558</sup>. Several other countries have been developing methods for applying HIA, supported by a range of capacity building activities (e.g. Slovakia <sup>557</sup>) as was the case in Slovenia, as described in previous chapters of this thesis.

Various approaches have been developed in these countries, influenced by HIA methods elsewhere in Europe, particularly the UK, Sweden and the Netherlands. Such HIA ‘toolkits’ are widely available in the published literature, or on the internet, and have many methodological similarities <sup>54</sup>. A second approach, environmental health impact assessment (EHIA), is more specifically focused on the narrower environmental health perspective. Examples can be found in Poland, Hungary, Lithuania, Czech Republic, Slovakia and Estonia, with EHIA being applied to projects such as air pollution and waste management <sup>559</sup>. In the process of developing National Environmental Health Action Plans<sup>560</sup>, the WHO Regional Office for Europe has worked with national environmental health agencies to develop an approach for integrating health into environmental impact assessment <sup>559</sup>. The EU has also funded technical assistance to strengthen EHIA. For example, an EU project in Poland, delivered by the Dutch Ministry of Health and the Netherlands School of Public Health, assists compliance with the EIA directive (*D. Aarendonk, personal communication*). EHIA and HIA should thus be seen as complementary applications.

**Table 13-2     HIA projects and development activity in new Member States**

Country	HIA guidelines and/or training	HIA projects	Administrative level at which HIA conducted (national, regional, local)
Czech Republic	Health risk assessment (National Institute of Public Health, Prague) Health Impact Assessment in the Hygiene Service <sup>561</sup>	Development regional plan- strategic health plan (planned)	Regional
Estonia	Guidelines for health impact assessment of municipality policies (Estonian Centre for Health Promotion 2002)	Pilot project: health impact assessment in Rapla municipality (in progress)	Local
Hungary	National HIA Workshop (December 2003)	Part of ongoing EU and WHO co-funded project mapping the use and context of HIA <sup>562</sup>	National
Lithuania		Annual report of the National health Council health policy assessment (1998, 1999, 2000) Toxic substances health impact assessment (2003 planned) Environmental health impact assessment of waste management system, Siauliai region Development of HIA strategies	National  National Regional
Malta		Consideration of health issues in EIA for abattoir waste incinerator (preliminary HIA)	Local
Poland	Technical assistance by the EU to strengthen Environmental health impact assessment to assist compliance with the EIA directive (pers comm.)	Part of ongoing EU and WHO co-funded project mapping the use and context of HIA <sup>562</sup>	National
Slovakia	Health Impact Assessment in the Hygiene Service HIA Workshop for 9 central and eastern European countries (2002, 2003) <sup>557</sup>	-Part of ongoing EU and WHO co-funded project mapping the use and context of HIA <sup>562</sup> -WHO healthy cities network PHASE project are developing: a HIA Toolkit; a HIA training module; a resource pack to support planning for health and sustainable development. <sup>563</sup>	Local and National
Slovenia	2 day HIA training course run at National Institute of Public Health (2002) <sup>564</sup>	Part of ongoing EU and WHO co-funded project mapping the use and context of HIA <sup>562</sup>	National

Source: Welsh Assembly Government<sup>551</sup>, Lock et al (2003, 2005) <sup>127 138 565</sup>, Wismar <sup>562</sup>, den Broeder <sup>131</sup>

Clearly, progress has been made in establishing a theoretical and political basis for HIA in Europe, and a range of methods for predicting health impacts have begun to be developed. Although methodological progress has been made, it may now be that HIA methods have reached a stage at which consensus would be possible and useful <sup>566</sup>. Studies of HIA have identified several research polarities; quantitative versus

qualitative evidence, participative or expert approaches, rapid or in-depth methods, and separate HIA or integrated with other impact assessments (see discussion later in this chapter). Although in the early days of HIA these debates were more vocal <sup>54 111</sup> more recently the concept of HIA has moved to one whereby any approach to undertaking HIA can be justified as long as it is ‘fit for purpose’<sup>567</sup>. It is unclear whether this is a pragmatic response to the world of decision-making, or a response to the difficult methodological challenges that HIA poses. In practice, it means that HIA is promoted as a flexible and adaptable approach to help those developing and delivering policies and one that will improve the quality of decision-making in areas that impact upon public health. However this pragmatism has to be balanced against the need to ensure that policy is based soundly on evidence.

### ***Clarifying the aims of HIA***

Despite the wide range of methods used and the diversity of applications of HIA across Europe, the majority of work described as HIA has some common characteristics<sup>567</sup>:

- It attempts to predict the consequences of adopting different options;
- It is intended to influence and assist decision-makers.

Hence, a definition based on these characteristics implies that HIA aims prospectively to assess the potential health impacts (both positive and negative) of policies over a timescale that enables influence on the decision-making process <sup>54 103</sup>. HIA can be thought to influence decisions in four ways:

- raising awareness among decision-makers about the relationship between health and other factors, such as the physical, social and economic environment, so that they consider health effects during planning;
- helping decision-makers to identify and assess the potential impact of a specific proposal on population health and wellbeing, and on the distribution of those effects within the population (i.e. issues of equity by considering health inequalities or the impact on specific vulnerable groups);
- HIA can identify practical ways to improve the outcome of proposals, by producing a set of evidence-based recommendations that feed into the decision-making process;
- helping stakeholders affected by policies to participate in and contribute to decision-making.



Whatever methods are used, the ultimate purpose of HIA is to inform and influence subsequent decision-making. HIA has not merely developed as a research tool to generate evidence on a policy topic; it is a political tool to aid decision-makers. However the implementation of HIA, and thus the ultimate influence that can be achieved, is limited, especially in such complex policy sectors as agriculture or the environment. These include uncertainty about the stage of the policy process at which a HIA should be undertaken, the nature of stakeholder involvement, deficiencies in the evidence-base, lack of capacity, and difficulty embedding HIA in political and organizational culture. These issues will be discussed in the subsequent sections of this chapter.

### ***Participation and stakeholder involvement***

In the few evaluations of policy HIA's conducted so far, the advantages perceived to have been conferred by the HIA have included the strengthening of policy-makers' understanding of interactions between health and other policy areas, with associated improvements in inter-sectoral relationships<sup>138 568 569</sup>. This has been facilitated by broad stakeholder involvement when it has been included. For example, in Slovenia, the inclusion of a broad range of stakeholders in the discussion of agricultural policy was a very important part of the process. Engagement of other sectors in HIA workshops widened the perspective taken, increased understanding of public health issues, and created shared agendas for future policy negotiations.

Another perceived strength of HIA is that it employs a more participatory approach than do many other methods of informing decisions about public health issues, by involving stakeholders in defining the scope of the research undertaken, the evidence gathering, and sometimes in reaching conclusions and recommendations. There is broad agreement from researchers and practitioners that stakeholders should be involved in HIA but it is still unclear how this involvement contributes to the assessment. Furthermore, there are contrasting opinions about the value of participation. One view argues that communities are 'not necessarily well-informed about potential health impacts' and likely to assess proposals from 'their own subjective viewpoint'<sup>570</sup>. But other researchers argue that this subjective viewpoint is a core component of a HIA; such 'lay knowledge being essential if one is to focus on the determinants of the health determinants' and to understand how a proposal can be modulated by interaction with social structures and human contexts<sup>570</sup>.

Participation in itself may bring additional benefits. Several HIAs have shown how participation creates new partnerships <sup>135 568 571</sup>. This was also true in the HIA undertaken in Slovenia as part of this thesis. Some people use HIA more explicitly as a tool for community development and look at how different approaches to HIA can increase community understanding, both in terms of the scope of health issues affected and the mechanisms of decision-making works and how it can be influenced <sup>572</sup>.

Yet there has also been criticism of participatory approaches to HIA. Such wide-ranging stakeholder involvement may not always be necessary, nor useful, particularly if conducted badly <sup>573</sup>. Broad participation has not been a feature of all HIAs in pre or post 2004 Member States. For example, two assessments of the health impact of the EU's Common Agricultural Policy have been conducted by the Swedish Institute of Public Health <sup>57 58</sup>. The most recent one <sup>58</sup> contributed to improved understanding by the agricultural sectors even though it was a desk-based expert-led study .

Although it is intuitively appealing, given the imperative to promote democratic values, participation is very difficult to organise and to conduct well <sup>573</sup>. There are clear divisions in the HIA literature about the importance attached to participation in HIA design. The harshest critics argue that, although many analysts claim to undertake participatory HIA, often the participation was merely tokenism, merely reinforcing community divisions and marginalising hard to reach groups <sup>573</sup>. Achieving genuine participation in policy-making is most difficult where the number of stakeholders is large and interests conflict.

There are, however, some factors that need to be included in the design of a HIA if it is to seek to be participative. These factors are common to any participatory rapid appraisal method. They include identifying all relevant stakeholders and approaches to ensure maximum participation. Identifying stakeholders requires knowledge of the subject of the HIA, the project or programme being assessed and the area or communities affected. It also necessitates identifying the correct individuals from a range of organisations or stakeholder groups that can represent their community (assuming that general public open events are not held). However, ensuring participation of stakeholders is more complex and involves work in encouraging interest and engagement in both the HIA and the project or policy being assessed. This is particularly important for many people who are not represented by organisations or community groups, such as those with little or no formal education and hard to reach

groups<sup>112</sup>. There is clearly a need for a sound theoretical underpinning of the role of participation in health impact assessment as well as greater empirical evidence on how to use participation most effectively in HIA.

### ***Predicting health impacts***

Several issues are unresolved in relation to the methodology used for HIA, many of which are concerned with predicting health impacts. These include the definition of health and the nature of evidence utilised in a HIA<sup>54</sup>.

Although there is increasing agreement about the wide variety of factors that influence health, their comparative importance varies between professionals and the public. In order for HIA to be a valid tool, a shared definition of health is needed. A failure to achieve such a consensus affects the ability to measure health impacts in various settings. At present, different models of HIA measure health impacts in different ways. Most models of HIA, including that applied in Slovenia, use some form of a checklist-based procedure, in which the perceived determinants of health are used as markers for changes in health risks. For example, employment levels may be used as a proxy for community health status. Unfortunately causal pathways are so complex that it is often difficult to say whether a proxy outcome will definitely be good or bad for the health of a population. Will a development such as replacing a derelict industrial site with new offices increase local employment? And if it does, will this improve health? Such health indicators can provide some indication of progress towards potential health improvement but this is not necessarily equivalent to measuring health impact.

While some countries have used the more limited EHIA approach, so far the most common approach to HIA has been one based on broad health determinants. This means that HIAs will confront considerable uncertainty when they seek to predict actual health impacts. For many policies, especially those implemented at a supra-national level, where even the immediate effects are often unclear<sup>127</sup>, the causal pathways are complex, with the current evidence base patchy and often irrelevant to concrete policy options<sup>111</sup>. Methods to assemble the evidence to enable HIA to contribute to decision-making remain poorly developed<sup>111 87</sup> and often require a trade-off between speed of working and depth of analysis.

A key debate in the HIA literature concerns how to identify and assess evidence for predicting health impacts. One of the major criticisms of HIA is that the methods of

collecting and analysing evidence are usually not sufficiently 'scientific', by which is meant rigorous and able to withstand scrutiny. The HIA literature is very clear that the current evidence base in relation to many health determinants is inadequate to inform the process of assessment effectively. Yet this problem is not unique to HIA but is shared by all evidence-based approaches to public health policy making. In a HIA, evidence of actual or potential health impacts can come from a range of sources including epidemiological evidence, economic data, local routine data sources from health and other sectors, and qualitative sources of data collection (some of which may be gathered specifically for the HIA). In practice, the principal sources of evidence in completed HIAs have come from literature reviews and qualitative research. The evidence base available to support the HIA process is often of poor quality, is inconclusive or incomplete, or is difficult to locate. Unfortunately epidemiology and related health sciences, which could contribute to HIA, have paid relatively little attention to the total causal pathways (including proximal and underlying factors) and the multiple interactions between risk factors. Yet the need for appropriate information on health determinants means that HIAs will confront considerable uncertainty in making definitive conclusions about potential health impacts. HIA practitioners thus have to acknowledge the constraints that limit them to making recommendations based on the "best available" evidence, given limits to time and other resources.

There is much debate about what is the 'best available' evidence. Many scientists argue that quantified estimates are more influential but it should be remembered that not everything that can be quantified is important, that things should not be quantified if this cannot be done robustly, and that not everything that is important can be quantified. Often the most useful information is not routinely collected. Too often there is insufficient time or money available for collection of primary data. Although it may be preferable for decision makers to have a quantitative measure of health impact, the limitations of qualitative estimates may have to be accepted as the best evidence available. This may limit the strength of the recommendations an assessment can make both in terms of the certainty and size of an impact <sup>111</sup>. This was the case in the HIA conducted in Slovenia. Other impact assessment methodologies, such as EIA, are also constrained by poor data. It is arguable that HIA should learn from the experience of EIA and concentrate more on working within the constraints of the evidence rather than waiting for the evidence to become available? However qualitative assessments are

often sufficient to reveal the direction of change, especially at early stages of policy development.

Although there is wide acceptance that evidence from a variety of sources is necessary in undertaking HIA, this creates another crucial challenge for HIA. Prioritising and making recommendations on the basis of evidence from different sources and using different methodologies is fraught with difficulty. There are very few frameworks that have been developed to tackle this issue, and none have been widely implemented or tested. HIA practitioners have to be aware that the conclusions from any review of evidence can be mixed, contradictory or limited, and so an important part of the process has been to involve key stakeholders to ensure that any recommendations are based on a clear understanding of their different perspectives given the nature of the evidence base available, and are reached by consensus. This approach has been taken in a number of policy-related HIAs, including that undertaken in Slovenia.

HIA aims to influence the decision making process in an open, structured way. To do this it has to acknowledge that assessing and ranking evidence is not a wholly objective process and involves a series of value judgments. There are no validated methods used in HIA to prioritise evidence from different sources, and political imperatives are likely to affect the outcome. The balance between objective evidence and subjective opinion should be explicitly recognised in reports of HIA assessments. Looking to the future, there is a need to develop new frameworks for gathering, interpreting, and prioritising evidence from different sources to support evidence based policy making involving HIA. One possible way forward draws on methods from operational research, such as modelling and decision analysis. Their practical use in HIA has, however, yet to be explored. This does, however, require availability of appropriate information on how different determinants of health impact on populations. Clearly, the Global Burden of Disease is a contribution to this process.

### ***Institutionalising HIA in the policy process***

The literature on HIA discusses the need for institutionalising this approach. These could include legislating to embed it within the decision-making process for new policies or other regulatory measures.

Other impact assessment methodologies are already applied at the level of the EU and individual Member States. The first European directive on Environmental Impact

Assessment (EIA) was adopted in 1985<sup>574</sup>. There is also experience with social impact assessment, sustainability assessment and integrated impact assessment. The last of these has been developed in the context of the complex challenge of identifying the implications of long-range trans-border pollution and involves the integration of many diverse sources of data. A legal basis for assessing policy health impacts in the EU emerged in Article 129 of the Maastricht Treaty (1993) and remained in Article 152 of the Amsterdam Treaty (1997). Article 129 on public health stated that 'health protection shall form a constituent part of the Community's other policies'. However as Article 129 precluded harmonising legislation, it had little influence on policy within Member States<sup>575</sup>. It also did little to foster an inter-sectoral approach to policy at a European level<sup>576</sup> as, despite the apparent intentions of those drafting Article 129, there are few means to implement it. Article 152 of the Amsterdam treaty (ratified in 1999), stated that 'a high level of human health protection shall be ensured in the definition and implementation of all community policies and activities'. This strengthened further the case for EU action, creating an opportunity to develop HIA as a means to achieve assessment of health impacts. In contrast, there is currently no statutory duty in law in any European country to undertake HIA.

It remains unclear who should be responsible for initiating HIA in the EU (the Commission, the European Parliament or Member States). While there has been much discussion about integrating public health into other policies, the only examples of progress have been pilot HIA projects funded through Directorate General (DG) Sanco, as part of the EU Health Strategy 2000, and the current public health programme 2003-2008<sup>577</sup>. An initial guide to assessing health impacts of other policies was published by DG Sanco<sup>578</sup> but has yet to be implemented. A more recent EC funded project aims to develop a generic methodology for HIA of EU policies and has been piloted on the European Employment Strategy<sup>579</sup>.

HIA is a cross-cutting theme in the EU's current public health programme. Yet despite its presence there, there remains some scepticism about its future potential at the level of the EU<sup>580, 513</sup>. Even if implemented more widely, it is not clear how HIA would be integrated into policymaking. Health is, of course, not the only consideration in policymaking and final decisions will take account of a number of issues. Decision making may involve trade-offs between different objectives, with health competing with economic, environmental, employment, and other considerations. Achieving a

balance between these factors is a political matter but a realistic aim is to ensure that possible health consequences of other policy sectors are, as a minimum, not overlooked. In this way, any negative impacts on people's health and wellbeing can be mitigated.

The voluntary status of HIA within the EU contrasts with that of EIA and Strategic Environmental Assessment (SEA), which do have a statutory legal basis <sup>574 577 581</sup>. As noted above, while health protection is defined in EIA legislation, in practice, little has been achieved in integrating health considerations into the process <sup>110</sup>, either being completely absent or restricted to technical issues such as levels of pollutants. The ownership of the EIA, SEA or other impact assessment processes by agencies that have no direct stake in population health is seen an obstacle to the effective integration of health concerns. Some recent European initiatives are attempting to strengthen the health elements of EIA. One approach involves so-called 'integrated impact assessment tools'. The EU is currently in the process of developing integrated approaches for screening new proposals <sup>580</sup>. Another approach is to integrate aspects of HIA in a new European legal protocol on SEA <sup>110</sup>, launched at the 5<sup>th</sup> Pan European Ministerial Conference on Environment in 2003. The protocol offers a potential mechanism to institutionalise HIA in European law <sup>110</sup>.

Ultimately, if HIA is to contribute to policy-making, it must be integrated with administrative processes, in a similar way to EIAs. Despite considerable experience over several years, only one Member State and one region, The Netherlands and Wales, have established national, resourced HIA units operating as part of government <sup>131 582</sup>, <sup>572</sup>. In many countries HIAs have been conducted on an ad hoc basis, although some have had a clear mechanism to feed into government strategy making. Such approaches have included joint ministerial committees or interdepartmental working groups (e.g. Slovenia, UK), although the public health benefit of this approach has not been established firmly and within the UK government, HIA no longer appears to be a current focus of political attention. A failure to embed HIA in the organizational structure of decision-making bodies reduces the scope for strengthening inter-sectoral working. This was the case in British Columbia, Canada, where, following political changes, HIA fell off the policy agenda despite having previously been located within the cabinet <sup>583</sup>. In Lithuania a more systematic approach has been piloted to embed HIA in administrative processes and structures <sup>131</sup>. However, while this approach has

yielded some valuable insights, it was found to have limitations both in its ability to produce practical recommendations and its failure to give sufficient recognition to the influence of different actors on the process. It is likely that difficulties in institutionalisation of HIA and inter-sectoral public health will be similar in all EU Member States, whatever approach is taken.

### ***Capacity for HIA implementation***

Even if a decision was made to institutionalise HIA within Europe, a lack of human resources remains a major constraint in many EU members states <sup>138 557 558</sup>. The ability to assess health effects of policies in other sectors using evidence-based approaches requires people with appropriate skills. In several of the new EU Member States the public health community has yet to complete the transition from the old environmental health and hygiene model. In this system, HIA is interpreted as a narrow technical exercise, often confined to activities such as toxicological analysis of water or air samples. Modern public health, which takes account of broader health determinants, such as the impact of policies on employment and income distribution, is a relatively new approach, although where investments have been made they have achieved considerable success, as in Hungary <sup>584</sup> and the Baltic States <sup>585</sup>. Another barrier to undertaking effective HIA is a lack of mechanisms by which public health can work with or influence other policy sectors. The narrow focus of public health in former communist countries of central and eastern Europe contrasts with a broader multi-sectoral approach in some pre-2004 Member States, such as the UK, The Netherlands or the Nordic countries (although in others, such as Germany and France, the public health focus has also been narrow). In the absence of formal mechanisms for involvement, several countries have established 'ad hoc' approaches, as in Slovenia and Malta.

### ***Conclusions***

HIA is a new approach to tackling wider public health concerns. It has come at a time when there is increased recognition among senior decision-makers that health can only be protected and improved by coordinated efforts in many sectors. In many countries, HIA has been seen as a means by which inter-sectoral action for health can be put into practice.



To date HIA has had a varied influence on decision-making across EU countries, largely dependent on the degree of political support. Methodologically it has strengths and weaknesses. The importance of HIA as a public health method is that it focuses on social and environmental justice, uses a multi-sectoral and often participatory approach, and is flexible, recognising that health information has to input into decision-making in a timely manner. By using a mixed methods approach it strives to give equal weight to qualitative and quantitative methods. However the lack of a suitable evidence base and methods to prioritise evidence from a range of different sources has meant that HIA has often been limited in the strength and certainty of recommendations it can make in terms of health outcomes. Other methodological approaches have also tried to tackle the complexity of informing public health decision-making, and have struggled with similar problems. Some of these take more qualitative approaches such as stakeholder analysis or option appraisal methods, while others are more quantitative, such as modelling and decision analysis. Unless there are more evaluations of HIA addressing a wide range of policies, and longer term monitoring of the impact of HIAs, then the approach may lose credibility and influence.

## **Chapter 14 Conclusions: using public health evidence to influence food policy**

There is now sufficient evidence to understand how agriculture and food policies in Europe increase exposure to risk factors for the major health problems in Europe, in particular non-communicable diseases and obesity. This thesis not only adds to this body of evidence but starts to explore the different types of evidence, and the processes that produce and disseminate evidence for decision-makers in different contexts. It has become clear from this thesis that more work needs to be done to explore the complex relationship between evidence and public health policy.

This concluding chapter discusses factors that influence the uptake and application of evidence in the policy process, and the role that burden of disease analysis and health impact assessment play. It then looks briefly at the role of evidence compared with other factors in influencing health considerations of food policies in Europe. Finally it discusses future research directions that would facilitate the use of evidence to ensure that policies on food and public health are more closely aligned.

### ***The role of public health science in health improvement***

Epidemiological research evidence has played an important role in public health improvement in the 20<sup>th</sup> century, for example in understanding the role of smoking in the causation of lung cancer. At the end of the twentieth century there was increasing emphasis on the genetic and molecular basis of disease. The implications of this shift for public health are important because molecular and genetic science emphasises the technical aspects rather than the social and environmental approaches to public health. Health economics has also become increasingly important in public health research; for example the World Bank has identified a cost effective package of public health interventions<sup>586</sup> which included childhood immunisation and school programmes, programmes to reduce tobacco and alcohol consumption. While it is of course important for policy makers to ensure that resources are used efficiently, the growing evidence on economic approaches used by the World Bank and other policy organisations (such as the National Institute of Clinical Excellence in the UK), reduces public health to a series of specific interventions that can be applied in any context. This is clearly removed from the reality of the social and environmental context in which many public health issues exist, and stands in contrast with the contextually embedded nature of many of the social and public policy initiatives that have

historically had large impacts on population health, such as the clean air act and improvements in water, sanitation and housing in the 19<sup>th</sup> and 20<sup>th</sup> centuries.

The complex causal pathways involved in many public health issues, including the rise in obesity and cardiovascular disease worldwide, means that the traditional scientific paradigms for collecting public health evidence, such as those exemplified by the National Institute of Health and Clinical Evidence and the Cochrane Collaboration, will only provide some of the evidence required by policymakers to create effective social and environmental policy that can improve population health.

It is clear from this thesis that understanding how public health research evidence can better influence policy not only requires knowledge of the most appropriate methods of evidence production, but also an understanding of the nature of the policy process, the place that evidence can play within it and the range of other factors and stakeholders that compete with health evidence to influence policy-making.

## ***Evidence and the policy making process***

### **The role of burden of disease analyses and health impact assessment in the policy process**

This thesis has explored the development and application of two different methodological approaches for producing evidence to inform policies that seek to improve health by increasing fruit and vegetable intake. But how have these methods fed into the policy process, and how can this knowledge improve the evidence-basis of public policymaking (assuming that policy is based to any extent on evidence)?

Some of the specific issues affecting both approaches, including their methodological limitations, have been discussed in chapters 9 and 13. In summary, the major criticism of burden of disease analyses is that, because they are based on aggregate indicators of individual health, they simply describe health in a population rather than inform the choice of what should be done to tackle the issue. However, it can be argued that this type of public health evidence has an important role as one of the factors responsible for influencing and setting the policy agenda. Despite the limitations of the GBD study, it is important to recognize the benefits that the presentation of comparable information can bring to health policy-makers. The Comparative Risk Assessment component of the 2000 Global Burden of Disease study was an important factor in getting a wider range of public health issues onto the policy agenda. This was especially true in the

case of low fruit and vegetable consumption. For many years fruit and vegetable intake was not considered a significant risk factor for cardiovascular disease, so that public health policies focused on smoking, high plasma cholesterol, high blood pressure, and obesity, considering fat intake as the only dietary risk factor. Often in the absence of standardised comparable data, health statistics are provided to decision-makers and the public by advocates with specific agendas, with the result that the information they provide is filtered or biased in its presentation.

The Comparative Risk Assessment project provided timely objective information on the magnitude of twenty six risk factors, obtained using uniform methods, for all world regions. The population health effects of dietary intake of fruit and vegetables can thus now be compared directly with the effects of other risk factors, including smoking, obesity, air pollution and unsafe sex, across the world. It has proved to be a means of stimulating decision-makers to consider a wider range of health determinants when formulating public policy. The findings of the work presented here suggest that nutrition, and specifically fruit and vegetable intake, should be much higher on the agenda of those who seek to address the increase in major non-communicable diseases worldwide. The inclusion of the findings from this thesis in the World Health Report <sup>144</sup> was a major step towards the acceptance of the importance of fruit and vegetables in international policies tackling non-communicable diseases. For example, in 2003, WHO and FAO launched a new joint Fruit and Vegetable Promotion Initiative <sup>527</sup> as part of the Global Strategy on Diet, Physical activity and Health (endorsed by the World Health Assembly 2004) <sup>587</sup>.

Contemporary public health policies have tended to focus on the promotion of healthy diets. In terms of fruit and vegetable consumption, a number of national and international bodies advocate an increase in intake of fruit and vegetables to 400–500 g per day (excluding potatoes) <sup>266</sup>. This has been translated into national health promotion campaigns, including the ‘5-a-day’ promotion programmes in the USA and the United Kingdom and similar initiatives in other European countries <sup>588</sup>. The evidence from the burden of disease analyses for fruit and vegetable intake also serves a purpose in challenging current policy recommendations, and suggests that this target, which was originally reached by expert consensus, should be the minimum policy goal.

While the summary information on disease burden from individual risk factors, considered alone as well as relative to other risks, is of great importance for public

health policies and programmes, it does not permit a more thorough understanding of the components which contribute to global and regional disease burdens. Given the complexity of risk factor epidemiology, it is critically important to present findings in as much detail as possible to facilitate their use.

An understanding of how this research can be best applied is crucial. While the estimates of the burden of disease results were important in placing fruit and vegetables on the worldwide public health policy agenda, they were not a sufficient basis for policy formulation as they say nothing about how interventions are likely to reduce a problem, or about the opportunity cost of allocating money to one public health issue rather than another. Burden of disease studies on their own are unlikely to help decision-makers make decisions about efficient use of resources. In health care policy such evidence usually comes from randomised controlled trials and meta-analyses, ideally combined with cost-effectiveness studies. The limitations of burden of disease estimates were recognised by the WHO during the design of the joint WHO-FAO Fruit and Vegetable Promotion Initiative. As part of the initial strategy discussions, a multi-disciplinary research committee identified a number of gaps in the evidence base which would assist both the UN and national governments to create effective policies to improve public health by means of diet. This led to the commissioning of further research by the WHO, including a systematic review, conducted by myself and colleagues (not discussed here) of the effectiveness of interventions and programmes worldwide in increasing fruit and vegetable intake<sup>588</sup>. This further research has been useful in enabling WHO to provide advice on means of increasing fruit and vegetable intake, but has not been as successful in engaging other policy sectors, such as agricultural producers and food processors, essential to the broader success of the initiative (*I Keller, personal communication*). This has been due partly to the lack of integration of scientific disciplines, and consequent lack of multi-disciplinary, multi-sectoral research. For example, the systematic review of interventions included agricultural studies which sought to increase production of home grown fruits or vegetables (such as education for local farmers, micro-credit schemes for buying seeds) but most studies had not sought to measure any change in diets or other proxy health outcomes<sup>588</sup>.

It is clear that to tackle public health problems in such complex policy scenarios as food and agriculture policy, evidence from a wider range of sources than that from

burden of disease and similar studies is required. In this thesis, I have presented health impact assessment as one method that can provide an evidence-based approach at directly influencing public policy development, particularly of non-health sector policies. As discussed in chapter 13, HIA has a number of methodological strengths and weaknesses. It is important as it has been designed specifically to feed evidence directly and explicitly into the policy process. In the future, the influence of HIA may be affected by a number of factors, one of which is the breadth of the evidence base that it requires, but this problem is not unique to HIA as it raises wider issues relating to the limitations of evidence based public health approaches. HIA needs to be able to develop methods to overcome the problems arising from this limited evidence base, including how to combine and weight evidence explicitly from different sources when making recommendations. To date these have not adequately been addressed. It may need to learn or adapt approaches taken from other methods of complex evidence synthesis, such as decision analysis, which has the benefit of developing models which can deal with the uncertainty where there is inadequate evidence about one or more elements along the health pathway<sup>589</sup>.

It is clear from the research conducted for this thesis that a range of methods will be required to generate an appropriate public health evidence base for public health policy. Although as the HIA shows, it is unlikely that the evidence base for public health policy will ever be simplified into a hierarchy of evidence such a that in which RCTs are seen as the gold standard. However, we need to improve our knowledge about which methodologies are most effective in different policy contexts, and in fulfilling the different requirements of different policy contexts. It should be apparent that evidence demonstrating priorities for public health action will be different from the type of evidence required for planning, policy implementation or evaluation.

In the case of this thesis, the findings of the burden of disease study could be seen as key evidence to stimulate policy interest and action. Yet although it was a necessary piece of information for raising awareness of the importance of fruit and vegetables as a policy issue, the research was not sufficient for policy formulation, leading to the commissioning of new research by policy-making bodies. In the case of the policy HIA in Slovenia, the findings of the national burden of disease analyses were seen as one piece of evidence that fed into the HIA, describing the health problems of the population which were already known. However, as with the WHO-FAO fruit and

vegetable initiative, other research evidence and information was required to assess the likely health impacts of the proposed agricultural policies. The HIA also showed that health evidence was only one of the factors leading to inter-sectoral policy action on agriculture policy in Slovenia.

### **Improving the relationship between research and policy impact**

There is still a disconnect between production of research evidence and its impact on decision-making. This thesis has concentrated on different methods of generating evidence which may be appropriate to different parts of the policy cycle. However, in order to improve how evidence is used by decision-makers health researchers must understand what role evidence plays amongst the full range of policy influences acting in the policy process. Researchers need to consider what factors impact on how and why evidence is taken into account, rather than concentrating on simply improving the quality of the evidence-base.

Part of the problem underlying this research-policy disconnect is the lack of understanding between researchers and policymakers. Innavaer et al <sup>90</sup> have described ‘the two communities thesis’, in which researchers see themselves as rational and objective, while policy makers see themselves as pragmatic but researchers as laden with jargon and politically-naïve.

For example, limitations of the evidence-base have been identified as a barrier to implementation of HIA by researchers <sup>54</sup>, but this is not the only reason that methodologies such as HIA have had little influence on decision-making. As was seen in the use of Health Impact Assessment by the Government of British Columbia (see chapter 12), HIA fell off the policy agenda after a change in political leadership led to a reorientation of health policy away from public health.

The barriers to evidence based policy are numerous and well recognised, and include factors that have their basis in both the research process and the policy process. Some of these are summarised in Table 14-1.

**Table 14-1 Barriers to evidence based policy** (adapted from Hunter <sup>590</sup>)

The nature of research process	The nature of policy process
Complexity of evidence and disputes over methodological rigor	Balancing competing issues, and influence of political priorities
Temporal challenge- time taken to generate evidence exceeds time policymakers have to wait	Multiple, and often contradictory, goals of policymakers
Research evidence may be irrelevant, out of date, or inapplicable to policy context	Tacit knowledge valued over research evidence
Lack of consensus about evidence	Absence of a culture of evidence based policy
Too little attention applied to research implementation	Expressed desire for evidence used as an excuse for policy inaction

The solutions that are required to tackle the complex problems that policymakers face are rarely able to be translated simply from one policy setting to another. They often involve the interaction of a range of actors with different motivations, influenced by a variety of contextual factors <sup>591</sup>. It may be that research asks the wrong question for the policy context. Health impact assessment attempts to recognise the nature and demands of the policy process and provide the ‘best available’ evidence in a timely and pragmatic manner, which is adapted to each context. It also emphasises research from a wider range of disciplines and sources than that normally considered in evidence based medicine. It is similar conceptually to approaches such as realistic evaluation <sup>592</sup> which asks ‘what is it about this intervention that works for whom, in what circumstances’. In doing so realistic evaluation also draws on information from different sources of evidence and from a range of disciplines. However, HIA and realistic evaluation have often been neglected by the research community as they do not fit into discrete research disciplines that funding bodies support. The research community often fails to recognise, or consider important, which research questions are policy relevant. Research evidence that is contextually embedded is a challenge to the scientific establishment which sees science as providing universally generalisable answers <sup>591</sup>. But policy needs to be supported by systematic empirical evidence that also that fits with proposed policy, and which is timely, and easily implemented. Perhaps the focus of the research community needs to shift from the construction of a ‘perfect’ evidence base which is often remote from the real world situation, and devote more attention to how policy is made, and how evidence needs to be presented to influence the process.



This will require researchers to develop new skills to translate research findings. At present this is often seen as beyond the scope of a researcher's role, and is certainly seen as not an essential part of an academic career (for example, as measured by the United Kingdom's Research Assessment Exercise).

However, it is not just a communication failure by researchers. A number of authors have noted <sup>590 593</sup> that the policy community has a responsibility to be aware of the relevant evidence when deciding what to do. The non-rational, iterative nature of the policy process will mean that research evidence is inevitably only one of a number of factors (including ideology) influencing policy outcomes, many of which may overshadow the 'evidence-base'. To change this emphasis there are calls for all new policies to make a statement of the evidence consulted in their preparation, and state their reasons if they choose to reject it. Although this is not likely to become a reality in the near future, this could be seen as a rationale for those advocating greater use of health impact assessment. However, as can be seen from this thesis, the application of health impact assessment may need to be limited being more suitable for more tightly defined subjects, for example specific projects or local policy contexts, rather than large multi-sectoral national policies.

Systematic reviews have attempted to identify what is successful at bridging the research-policy divide <sup>90 594</sup>. One of the key factors appears to be ongoing interaction between researchers and policymakers. This dialogue must seek to foster a collaborative relationship with evidence based policy where researchers are able to understand the policy question and its specific context, and produce evidence that is timely and relevant <sup>591</sup>. This also requires translation and dissemination of the research in a number of ways that are often at odds with the current emphasis on publishing research in peer-reviewed scientific journals. Some approaches identified as important for dissemination include the need to provide brief research summaries with policy recommendations <sup>90</sup> or creation of networks that bring researchers and policymakers together<sup>594</sup>.

It is important to develop such approaches to maximise the likelihood that evidence will be considered by policymakers, while at the same time realising that they may still choose to ignore it due a number of factors beyond the control of the researcher.

## ***Increasing the influence of public health evidence in European food policy***

In Europe, the main emphasis of food and agriculture policy continues to be on food safety, which is considerably less important in terms of disease burden than diet<sup>595, 144</sup>.

*'If (food) policy were based on evidence we would see, for example, immediate action utilising all available policy levers to deliver a reduction in the incidence of heart disease and diet related cancers'*<sup>596</sup>.

However, if policy is to impact on rates of non-communicable disease there must be wide-ranging changes in many sectors. Current health promotion programmes have had limited success in, for example, increasing fruit and vegetable intake<sup>588</sup>. This is perhaps unsurprising given competing pressures on food and nutrition policy, such as intensive marketing of fast food or changes in the retail sector that favour large supermarkets in some countries. As dietary habits are embedded in cultural, economic and political structures, there should also be greater emphasis on promoting food policies that target the determinants of consumption rather than simply targeting individual behavioural change. Policy should aim to remove obstacles and enhance people's ability to eat healthy diets, including action on agriculture, food labelling, nutritional claims, advertising, nutrition programmes, and differential food taxation.

### **The case of overweight and obesity**

The policy response to the rise in overweight and obesity is a clear example of how public health and food policy has not been shaped by the evidence.

There is widespread agreement amongst scientists and policymakers that obesity is a major and growing public health problem. It has been estimated to cause at least 2.3% of the global disease burden<sup>144</sup>, and on current trends obesity will soon surpass smoking as the greatest cause of premature loss of life worldwide. Its prevalence has increased by between 10- 40% in European countries in the past 10 years<sup>597</sup>. One of the highest recorded increases has been in the UK, where obesity has trebled in adults between 1980 and 2002 (from 6% to 22% in men, and 8 to 22.8% in women)<sup>598</sup>. In children (aged 2-15 years) rates of overweight and obesity have also increased dramatically between 1984 and 2002 (from 5.4% to 21.8% in boys, and from 9.3% to 27.5% in girls)

<sup>598</sup>.

The consequences of obesity for health, psycho-social wellbeing, and the economy are substantial and well-known. Obesity is associated with an increase in many health problems, some of which primarily impact on quality of life, such as breathing, musculo-skeletal and skin problems and infertility, while also increasing the risk of premature death from disorders such as non-insulin dependant diabetes, gallbladder disease, cardiovascular disease (hypertension, stroke and coronary heart disease) and certain cancers<sup>599</sup>. In this way it affects life expectancy adversely; 8.7% of deaths in the UK <sup>600</sup> are estimated to be due to excess weight, with life expectancy 9 years lower for obese people than non-obese. The health consequences for children are less clear but a recent systematic review shows that childhood obesity is strongly associated with adverse cardiovascular risk factors in adolescence which persist into adulthood; overweight children become overweight adults, and there is significant psychological morbidity<sup>601</sup>. The psycho-social consequences for both adults and children reflect prevalent negative attitudes towards the obese, with discrimination in many areas of life, including employment, and are manifest as lowered self-esteem and increased prevalence of clinical depression<sup>602</sup>.

Economic costs of overweight and obesity in the UK have been estimated by the government at £6.6-7.4 billion per year in 2002 <sup>597</sup>. These include direct costs of treating obesity and indirect costs for premature mortality and sickness absence. Assessments of the direct cost of obesity to health systems in North America, Australia and Europe suggest that between 2 to 8% of total health care costs are attributable to obesity.

Why should the health sector think about agriculture and food policy at all when there are so many other pressures on health system resources? To some the answer is clear: agriculture policy has a strong influence on what food is produced, how it is produced, processed and sold, and is a key determinant of what people eat. However, many voices in the health sector continue to argue that diet is merely a matter of choice, focussing on individual behaviour and not on the environmental factors that might assist or impede healthy choices. Food and nutrition are at last high on the political agenda due to recognition that the rapid worldwide increase in obesity, and with it non-communicable diseases, is determined to a large extent by dietary factors. Much of the public debate on the international obesity problem is starting to reflect how different actors – e.g. government, the food industry, interest groups – determine the availability.

accessibility and affordability of healthy foods. Yet the health sector is left struggling with how best to support people to eat a well-balanced nutritious diet that will reverse these disease trends.

To date most policies tackling obesity have focused on changing the behaviour of individuals—on personal choice of diet and exercise—and cumulatively these have had little or no impact on the increasing prevalence of obesity. Although body weight is primarily regulated by a series of physiological processes that control energy balance, it is also influenced by broader health determinants. There is increasing evidence that the underlying causes of the obesity epidemic are societal and environmental, related to environments that promote excessive food intake of energy dense foods, particularly those high in saturated fat and sugars, and that discourage physical activity<sup>603 604</sup>.

Agriculture policy as well as general improvements in agricultural productivity has lead to rising dietary energy supplies in all regions of the world. Current food prices are relatively the lowest in history <sup>605</sup>. The per capita food availability on a global basis increased from about 2300 kcal per day in 1961 to 2800 kcal per day in 1998 and is expected to pass 3000 kcal per day around 2015. The daily energy requirement for an adult woman is 1900-2500 kcal (8,1-10,4 MJ/day) and that of a man is 2500-3200 kcal (10,4-10,3 MJ/day) depending on the level of physical activity <sup>606</sup>. According to the UN Food and Agriculture Organisation the rise in the dietary energy supply will continue worldwide for at least another 25 years <sup>605</sup>. The factors driving changes in global food production and consumption are of interest to the public health sector because the increase in food energy intake has been identified by several researchers as a key driver of the obesity epidemic worldwide in combination with an increasingly sedentary lifestyle <sup>542, 607, 608</sup>. Although not all countries have been able to document that the rising food supply is accompanied by rising energy intakes the rise in bodyweight strongly suggest that consumption is actually increasing worldwide.

How does agriculture policy contribute to this development? This thesis has discussed how agriculture policies have profound and complex effects on the food supply as well as on demand because policy creates production incentives for many commodities by providing market support. Together, OECD countries plough almost US\$1 billion a day into agriculture subsidies <sup>541</sup>. This is paradoxical considering the huge food surpluses characterising the agricultural sector in developed countries, particularly the EU, today. Another paradox is that subsidising agriculture makes food more expensive for

consumers due to loss of efficiency in production <sup>541</sup>, which in itself has a limiting effect on demand <sup>542</sup>.

However, despite advances in our understanding of the factors influencing food consumption, and an increasing evidence base on the effectiveness and cost-effectiveness of interventions for obesity prevention, governments have paid little attention to the development of effective obesity prevention and management policies. In the UK, the previous national public health target for tackling obesity was set in the Health of the Nation White Paper (1992) <sup>609</sup>, which aimed to reduce obesity prevalence to 6% in men and 8% in women by 2005. Obviously this has had little influence on the UK response to the continuing rise in obesity rates. It is only in 2004 that new government targets were set, placing obesity and overweight back on the UK government's health agenda <sup>610-612</sup>.

It is clear that the rational development of co-ordinated management of overweight and obesity is needed in the UK and across Europe. The UK House of Commons Health Committee Report on Obesity<sup>597</sup> stated that there was a need for more evidence and to find "the most successful and cost effective policies". It was the first national initiative to suggest the need for a comprehensive and integrated strategy that emphasises the environmental contributors to the obesity problem. Some other national policy documents have also acknowledged that improving diet and tackling the dietary causes of many non-communicable diseases is not simply about improving how to get the message across about behaviour change. In a recent study commissioned by the UK Treasury, obesity was identified as a key issue determining the future health of the population, and thus health expenditure. That report, 'Securing good health for the whole population' focuses on the wider determinants of health<sup>613</sup>. It builds on the previous Treasury commissioned study that concluded that the National Health Service (NHS) must focus more on health improvement and disease prevention rather than just treating ill-health. By doing so, it predicted, the NHS could save £30 billion by 2022, equivalent to half its current expenditure. Although this report accepts that individuals are ultimately responsible for their own health, it acknowledges that people need to be supported more actively to make better decisions because there are 'widespread . systematic failures that influence decisions individuals currently make'. It argued that these broader, systems issues can only be tackled by the collective action of national and local government, businesses, society and the voluntary sector. From this, and

evidence of effectiveness of interventions, it is increasingly clear that action to ensure good population nutrition needs both a well informed public that is able to make choices about their diet, and a multi-sector production system that provides access to a wide range of healthy affordable food.

However, despite this, the UK government, in its recent public health white paper, continues to emphasise the personal aspects of individual behaviour change<sup>610</sup> and places less emphasis on making legislative or policy changes that would affect environmental factors such as marketing of unhealthy foods to children, or the impact of the farming or retail sectors.

### ***Implications for the future direction of European agriculture policy***

Currently the EU Common Agricultural Policy (CAP) determines the major direction and scope of the national food policies across Europe and, indirectly, in many other parts of the world. Sadly in health terms the CAP should be seen as a ‘systematic failure’. In the book *Food Wars*, Lang and Heasman discuss why the productionist paradigm, exemplified by the CAP, prevails despite evidence of its limitations. Although a full discussion is beyond the scope of this thesis many of the issues were raised during the HIA in Slovenia and are discussed in chapters 11 and 12. In its simplest terms, the CAP fails to produce the range of foods that would allow the population of the EU to meet basic healthy eating recommendations. A recent analysis showed that if all of Europe suddenly decided (and was able) to eat according to internationally agreed dietary guidelines then the agricultural sector would not be able to meet the needs of the European population, given its current production focus<sup>77</sup>. This basic contradiction demonstrates a key failure of the CAP as the major determinant of diet.

Current European agricultural policy is not economically efficient, nor does it provide good health or value for money to its citizens. EU agricultural expenditure consumes nearly 50% of the total EU budget, and costs consumers and taxpayers €117 billion per year through higher food prices and taxes<sup>58</sup>. Ninety percent of citizens in a European wide survey of over 16,000 people want the CAP to ensure safe and healthy food<sup>614</sup>. It is clear that the CAP is not achieving this basic consumer goal. Public health costs include the impact on the poor of higher prices, and the externalised costs of non-communicable diseases and obesity through subsidies for the production and

consumption of animal fat, tobacco and alcohol, and supply of insufficient amounts of fruit and vegetables. The Swedish Institute of Public Health estimated that four CAP sectors (dairy products, tobacco, fruit and vegetables and alcohol) which directly or indirectly harm public health cost €3.4 billion per year <sup>58</sup>. Agricultural interests currently conflict with public health when subsidising the production and consumption of food. Current health goals therefore cannot be achieved without appropriate changes to agriculture policy.

Recent CAP reforms<sup>615</sup> have largely been driven by financial concerns arising from EU expansion, but it seems obvious that future reforms (including the revision of the fruit and vegetable policy currently being during 2006<sup>545</sup>) need to take public health into account as outlined in article 152 of the Amsterdam Treaty. The CAP still promotes the historical goal of delivering 'health' via higher productivity and food security. This fails to reflect the health concerns across Europe today, with increasing production of dairy products and livestock mirroring increases in the proportion of people eating diets high in animal fats and the concomitant rises in non-communicable diseases. It has been argued that the original CAP objectives are not in line with the needs of contemporary society and should be changed fundamentally <sup>616</sup>. However, the food policy process in Europe is not merely about reforming the CAP, it is a complex situation strongly influenced by the commercial agriculture and retail food industry<sup>596</sup>.

Although the basic aim of many agricultural policies is to provide adequate food for the population, in reality, the situation in each country involves a much more complex combination of agriculture, food, trade, and health. The broader public health issues that are raised by aspects of agriculture and food production are rarely considered by policy-makers. For example, nutritional issues are hardly ever discussed in the Agricultural Council or by DG Agriculture, where they obviously belong. Other questions related to the competitiveness and commercial interest of the sector are taking up the attention of policy-makers such as levels and type of support, food quality standards, protection of origin of foods, agrichemical and biotechnology use, foreign investment, food processing and product branding, the balance between food retail multi-nationals and primary producers, land ownership and international trade agreements within the World Trade Organization. This may partly be because public health researchers and practitioners do not engage in the agricultural policy process, but it should be also recognised that health evidence is competing against the policy

pressures of big agro-business, trans-national food retail companies and national agricultural interests in Europe, none of which have health as part of their agenda.

This thesis has highlighted some of the difficulties which need to be overcome to improve food and agricultural policy, nutrition and public health inter-sectorally at the European level. It is clear that, even if national governments wish to promote public health through improved farming and food policy, sometimes they are incapable of doing so because of the current drivers of European agricultural policy that exist centrally. These barriers to change need to be tackled urgently so that all countries can tackle the mounting public health and economic pressures created by the rising trends in obesity and non-communicable disease across Europe. Public health needs to be more pro-active at engaging with multi-disciplinary research to develop an integrated European agriculture and food policy, which balances competing and sometimes conflicting interests but which includes evidence-based public health as a core priority.

### ***Future research directions***

Despite the health sector continuing to produce evidence of the wide ranging negative health impacts of food and agricultural policy, so far there has been little change. What can the public health sector do to in the future to make a difference? One way to stimulate this could be to improve the evidence-base concerning the health impacts of agricultural policy in Europe. As we have seen, the relationship between policy and evidence is not simple, but assuming that evidence is going to be used to drive decisions at some level, increasing the impact of public health requires an increase in availability of evidence that is relevant to the EU context. This requires systematic evidence-based methods that will deliver clarity of evidence, but be relevant and timely in order to affect policy recommendations<sup>15</sup>. The public health sector must not only work to improve methods but also to apply these methods to the solution of real policy questions. One reason for the current lack of evidence is not that important agriculture and health linkages do not exist, but instead a reflection of a lack of funding for research in this area. Neither the health or agriculture sectors seem to prioritise such inter-sectoral research.

As seen in the research in Slovenia, health is of course not the only consideration in policymaking and final decisions will take account of a number of issues. Decision-making may involve trade-offs between different objectives, of which health will



compete with economic, environmental, employment, and other considerations. The balance between health and other impacts is political but a realistic aim is to ensure that possible health consequences of other policy sectors are considered and not overlooked. In order to achieve this goal, future public health research should not only focus on the evidence-base for health effects of specific interventions but also study ways to improve how evidence is made available for policymakers. This should investigate the effectiveness of inter-sectoral approaches to developing policy, and also mechanisms to improve dialogue and understanding between researchers and policymakers (as discussed earlier in this chapter). It has been suggested that public health could learn from the environmental sector about new ways of working, and specifically about how to create alliances with the agriculture and food sector <sup>596 616</sup>. Future inter-sectoral approaches need to ensure that food and farming policy gives equal weight to human health, environmental concerns and agriculture and rural interests. This requires overcoming the disinterest in agriculture shown by health ministries and public health officials. But equally we must improve the knowledge of agricultural decision-makers about the links between CAP policy, nutrition and health. Their knowledge of production, economics and technicalities of CAP policy instruments does not extend to what happens to their products, or how new markets can be created using health as a factor. Most importantly there is a need to get agriculture and health ministries in EU Member States to work together. Advocating a ‘whole system approach’ to food policy is not new. This concept underpins the recent launch of the Global Fruit and Vegetable Promotion Initiative, a joint venture between the WHO and the UN Food and Agriculture Organisation<sup>617</sup>, which forms part of the WHO Global Strategy on Diet, Physical Activity and Health<sup>14</sup>. The European Commission could apply a similar approach to the opportunities presented by the current reform of the CAP fruit and vegetable sector, where the health and agriculture sectors could easily work together for mutual benefits in a number of ways. Health impact assessment is clearly one approach that could prove a useful mechanism for achieving inter-sectoral working on health and agriculture at national and European level <sup>138</sup> but it is not the only means, and the effectiveness of these different approaches needs to be evaluated. In addition, research is required on the key skills that are needed to assist inter-sectoral collaboration for public health, including networking and advocacy and techniques to improve the translation of research evidence.

New public health research directions are needed to improve the translation of research evidence for policymakers. Currently public health decision-makers face, almost unaided, the extremely difficult task of integrating the results of research conducted using diverse methods over various topics to decide on the best use of their scarce resources. While increasingly provided with improved information support they currently lack any serious form of decision support. I propose to undertake future research to develop and test an analytical framework that will enable decision-makers to assess, more coherently and consistently, the comparative effectiveness and efficiency of simple and complex interventions targeted at different points in the determinant pathway for a public health issues or disease outcome. Initially I would propose to develop this research to provide an applied, updateable approach to evidence-based decision-making for preventing rises in population rates of obesity. The proposed research would develop a decision-tool based on Bayesian graphical modelling for simultaneously determining the cost-effectiveness of obesity interventions and the cost-effectiveness of alternative public health research strategies relevant to these interventions. This would allow comparison of interventions from different research disciplines, and allows for inclusion of causal pathways in the decision-model even if there is currently no scientific evidence available. The use of decision analysis will permit the revision of the results of such evaluations in the light of changed evidence or value judgements as they become available, yielding rapid reassessments of both the adoption decision (what options are cost-effective given the current evidence) and the research decision (what research is most cost-effective given the current uncertainties). This approach has been widely used in the health care sector to assess new services or treatments but has not been widely applied to public health. The aim of the output would be to enable stakeholders (such as health policymakers) without modelling expertise to be informed about the consequences of varying particular parameters/ interventions for preventing or reducing obesity. The value of this approach is that it explicitly enables consideration of multi-sectoral policy options and interventions.

## ***Personal reflection and learning***

I have learnt a great deal from conducting the research for this thesis. As intended, I have developed methodological skills in a number of areas, including nutritional epidemiology and a range of qualitative techniques required to successfully undertake HIA. For the Global Burden of Disease Study great thought had to be given to the most appropriate way of obtaining, organising and analysing food intake data, including the most appropriate approach to dealing with missing data. The comparative risk assessment approach also required developing a methodological approach to burden of disease analysis for food as a disease risk factor for the first time. My work has thus contributed to the body of knowledge on the methods that should be used in this field.

It is also appropriate to make some broader reflections on the work that went into this thesis. The complexities conducting research in countries with different languages and cultures to your own should not be underestimated. There are also difficulties in conducting research involving the study of policies in the process of being developed by countries (as in health impact assessment), as the policy process often means that the agenda and focus of the issues being assessed can change rapidly. Finally, applied public health policy research such as this is complex, requiring expertise in a number of different fields including epidemiology, policy analysis, qualitative methods, economics, applied to a number of different subjects including nutrition, agriculture, non-communicable disease. There is a danger of research efforts being spread very thinly. However, it is unclear how a systems-based public health approach can be taken to non-health sector policy such as this in any other way.

**APPENDICES**

## Appendix A: Global burden of ischaemic heart disease due to low intake of fruits and vegetables

Table A1 Attributable fraction of mortality (%)

<b>a</b>	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	36	34	26	31	25	34	24	30	17	22	10	14	19	25	22
AFR-E	NA	NA	NA	NA	41	41	36	38	35	40	32	37	22	28	13	19	27	31	29
AMR-A	NA	NA	NA	NA	37	39	35	37	33	34	31	32	21	22	15	15	22	19	21
AMR-B	NA	NA	NA	NA	41	42	42	37	39	40	39	39	28	28	20	20	32	29	31
AMR-D	NA	NA	NA	NA	35	33	26	32	27	35	28	32	22	26	17	19	23	26	24
EMR-B	NA	NA	NA	NA	35	33	29	30	29	31	27	27	22	23	15	16	25	24	25
EMR-D	NA	NA	NA	NA	34	31	28	31	26	33	23	28	17	21	12	13	21	24	22
EUR-A	NA	NA	NA	NA	28	27	26	24	25	22	21	22	16	17	11	12	16	14	15
EUR-B	NA	NA	NA	NA	27	30	29	31	26	27	28	29	21	21	16	16	23	21	22
EUR-C	NA	NA	NA	NA	39	41	38	42	38	41	37	41	28	30	20	22	32	28	30
SEAR-B	NA	NA	NA	NA	38	41	38	41	37	41	38	41	28	30	20	23	32	33	33
SEAR-D	NA	NA	NA	NA	37	39	37	39	37	39	37	39	27	29	20	21	32	33	32
WPR-A	NA	NA	NA	NA	30	31	29	28	25	22	22	22	17	17	12	13	18	15	17
WPR-B	NA	NA	NA	NA	30	32	30	31	29	30	31	33	24	26	19	19	26	25	25
World	NA	NA	NA	NA	36	38	34	36	33	36	32	35	23	26	16	17	27	26	26

Table A2: Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	36	34	26	31	25	34	24	30	17	22	10	14	23	29	26
AFR-E	NA	NA	NA	NA	41	41	36	38	35	40	32	37	22	28	13	19	32	35	34
AMR-A	NA	NA	NA	NA	37	39	35	37	33	34	31	32	21	22	15	15	28	25	27
AMR-B	NA	NA	NA	NA	41	42	42	37	39	40	39	39	28	28	20	20	37	35	36
AMR-D	NA	NA	NA	NA	35	33	26	32	27	35	28	32	22	26	17	19	26	30	27
EMR-B	NA	NA	NA	NA	35	33	29	30	29	31	27	27	22	23	15	16	27	27	27
EMR-D	NA	NA	NA	NA	34	31	28	31	26	33	23	28	17	21	12	13	24	27	25
EUR-A	NA	NA	NA	NA	28	27	26	24	25	22	21	22	16	17	11	12	20	17	19
EUR-B	NA	NA	NA	NA	27	30	29	31	26	27	28	29	21	21	16	16	25	24	25
EUR-C	NA	NA	NA	NA	39	41	38	42	38	41	37	41	28	30	20	22	35	33	35
SEAR-B	NA	NA	NA	NA	38	41	38	41	37	41	38	41	28	30	20	23	35	37	36
SEAR-D	NA	NA	NA	NA	37	39	37	39	37	39	37	39	27	29	20	21	34	36	35
WPR-A	NA	NA	NA	NA	30	31	29	28	25	22	22	22	17	17	12	13	21	18	20
WPR-B	NA	NA	NA	NA	30	32	30	31	29	30	31	33	24	26	19	19	28	28	28
World	NA	NA	NA	NA	36	38	34	36	33	36	32	35	23	26	16	18	30	31	31

Table A3: Attributable fraction of DALYs (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	36	34	26	31	25	34	24	30	17	22	10	14	23	29	26
AFR-E	NA	NA	NA	NA	41	41	36	38	35	40	32	37	22	28	13	19	32	35	34
AMR-A	NA	NA	NA	NA	37	39	35	37	33	34	31	32	21	22	15	15	28	26	27
AMR-B	NA	NA	NA	NA	41	42	42	37	39	40	39	39	28	28	20	20	37	35	36
AMR-D	NA	NA	NA	NA	35	33	26	32	27	35	28	32	22	26	17	19	26	30	27
EMR-B	NA	NA	NA	NA	35	33	29	30	29	31	27	27	22	23	15	16	27	27	27
EMR-D	NA	NA	NA	NA	34	31	28	31	26	33	23	28	17	21	12	13	24	27	25
EUR-A	NA	NA	NA	NA	28	27	26	24	25	22	21	22	16	17	11	12	20	17	19
EUR-B	NA	NA	NA	NA	27	30	29	31	26	27	28	29	21	21	16	16	25	25	25
EUR-C	NA	NA	NA	NA	39	41	38	42	38	41	37	41	28	30	20	22	36	34	35
SEAR-B	NA	NA	NA	NA	38	41	38	41	37	41	38	41	28	30	20	23	35	38	36
SEAR-D	NA	NA	NA	NA	37	39	37	39	37	39	37	39	27	29	20	21	34	36	35
WPR-A	NA	NA	NA	NA	30	31	29	28	25	22	22	22	17	17	12	13	21	18	20
WPR-B	NA	NA	NA	NA	30	32	30	31	29	30	31	33	24	26	19	19	28	28	28
World	NA	NA	NA	NA	36	38	34	36	33	36	33	35	23	26	16	18	30	31	31

Table A4: Attributable mortality (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	4	5	5	5	4	6	2	3	15	21	36
AFR-E	NA	NA	NA	NA	1	1	2	1	6	6	7	6	5	7	2	4	21	25	47
AMR-A	NA	NA	NA	NA	0	0	3	1	14	5	16	8	19	15	17	30	69	59	128
AMR-B	NA	NA	NA	NA	0	0	3	1	14	6	17	10	14	11	7	9	55	38	93
AMR-D	NA	NA	NA	NA	0	0	0	0	1	1	1	1	1	1	1	1	5	4	8
EMR-B	NA	NA	NA	NA	0	0	2	1	7	3	6	3	5	4	2	2	23	12	35
EMR-D	NA	NA	NA	NA	1	1	3	2	12	9	12	12	10	12	4	4	42	39	81
EUR-A	NA	NA	NA	NA	0	0	2	0	10	2	16	6	21	16	14	26	63	50	113
EUR-B	NA	NA	NA	NA	0	0	3	1	12	4	19	12	18	18	8	15	60	50	109
EUR-C	NA	NA	NA	NA	1	0	11	2	40	11	59	36	46	65	17	61	173	176	349
SEAR-B	NA	NA	NA	NA	1	1	3	2	9	6	13	11	10	10	4	5	40	35	76
SEAR-D	NA	NA	NA	NA	3	7	15	12	83	45	100	84	73	71	24	25	298	243	540
WPR-A	NA	NA	NA	NA	0	0	0	0	2	0	3	1	4	3	3	5	13	9	22
WPR-B	NA	NA	NA	NA	1	1	5	3	18	10	30	24	32	35	15	30	103	104	206
World	NA	NA	NA	NA	9	11	54	26	230	113	305	221	263	273	118	220	979	864	1844



Table A5: Attributable YLL (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	9	15	26	23	53	81	41	51	20	36	3	6	152	211	363
AFR-E	NA	NA	NA	NA	18	24	49	28	84	94	59	62	24	39	4	9	237	257	494
AMR-A	NA	NA	NA	NA	4	2	64	20	207	70	144	80	93	79	32	50	544	300	844
AMR-B	NA	NA	NA	NA	16	7	81	32	207	99	148	98	68	59	14	18	534	314	848
AMR-D	NA	NA	NA	NA	3	2	6	3	14	10	11	9	6	6	2	2	42	32	74
EMR-B	NA	NA	NA	NA	10	5	49	15	113	39	56	30	24	21	4	5	256	116	372
EMR-D	NA	NA	NA	NA	27	24	80	43	186	135	110	116	47	66	8	9	459	393	852
EUR-A	NA	NA	NA	NA	3	1	40	7	148	28	142	56	103	83	26	44	462	220	681
EUR-B	NA	NA	NA	NA	8	4	69	19	175	62	170	118	87	97	15	28	524	327	851
EUR-C	NA	NA	NA	NA	28	5	247	45	611	176	529	348	235	355	33	120	1683	1049	2732
SEAR-B	NA	NA	NA	NA	33	18	76	44	134	100	115	108	51	55	8	12	417	336	753
SEAR-D	NA	NA	NA	NA	88	231	348	287	1234	690	888	801	361	401	53	58	2971	2469	5440
WPR-A	NA	NA	NA	NA	1	0	10	2	34	7	28	11	18	13	6	8	97	43	140
WPR-B	NA	NA	NA	NA	41	22	125	68	274	161	268	230	157	192	33	63	897	736	1633
World	NA	NA	NA	NA	290	359	1268	637	3474	1753	2709	2117	1294	1503	240	434	9276	6803	16079

Key: NA, not applicable.

Table A6: Attributable DALYs (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	11	16	30	27	61	96	45	57	20	37	4	7	171	240	411
AFR-E	NA	NA	NA	NA	20	27	53	34	95	111	64	69	25	41	4	10	261	293	554
AMR-A	NA	NA	NA	NA	6	3	74	27	231	89	158	93	98	87	33	52	600	350	949
AMR-B	NA	NA	NA	NA	19	9	92	39	233	121	160	110	71	63	14	19	589	360	948
AMR-D	NA	NA	NA	NA	4	2	7	4	15	12	12	10	7	6	2	2	45	36	81
EMR-B	NA	NA	NA	NA	11	5	52	18	118	45	59	35	25	23	4	5	270	130	400
EMR-D	NA	NA	NA	NA	31	26	90	52	201	158	120	130	49	69	8	9	499	444	943
EUR-A	NA	NA	NA	NA	4	4	47	10	162	32	151	62	106	87	27	45	498	241	739
EUR-B	NA	NA	NA	NA	9	5	77	24	188	70	181	128	90	99	15	29	561	355	916
EUR-C	NA	NA	NA	NA	30	6	266	53	646	194	558	376	240	365	34	123	1775	1118	2893
SEAR-B	NA	NA	NA	NA	37	20	84	51	146	114	120	117	52	57	9	12	448	370	819
SEAR-D	NA	NA	NA	NA	105	245	407	351	1359	829	981	920	380	427	55	62	3288	2832	6120
WPR-A	NA	NA	NA	NA	3	2	12	3	37	9	30	13	19	15	6	9	106	50	156
WPR-B	NA	NA	NA	NA	46	25	147	85	316	198	292	259	163	201	34	65	998	834	1832
World	NA	NA	NA	NA	336	395	1438	777	3810	2077	2931	2379	1346	1577	248	447	10109	7652	17761

**Appendix B: Global burden of cerebrovascular disease due to low intake of fruits and vegetables**

Table B1 Attributable fraction of mortality (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	10	10	7	9	8	11	8	11	7	9	4	6	7	9	8
AFR-E	NA	NA	NA	NA	12	12	10	11	11	13	11	13	9	12	6	9	10	11	11
AMR-A	NA	NA	NA	NA	12	13	11	12	12	13	12	13	10	10	7	7	9	9	9
AMR-B	NA	NA	NA	NA	12	12	12	10	13	13	14	14	12	12	9	9	12	11	11
AMR-D	NA	NA	NA	NA	10	9	7	9	9	11	10	11	9	11	7	9	8	10	9
EMR-B	NA	NA	NA	NA	10	9	8	8	9	10	9	9	9	10	7	7	8	9	9
EMR-D	NA	NA	NA	NA	9	9	8	8	8	11	8	10	7	9	5	6	7	8	7
EUR-A	NA	NA	NA	NA	9	9	8	8	9	8	8	8	7	8	5	6	6	6	6
EUR-B	NA	NA	NA	NA	7	8	8	8	8	9	10	10	9	9	7	7	8	8	8
EUR-C	NA	NA	NA	NA	13	15	13	15	15	16	16	17	14	14	10	11	14	13	14
SEAR-B	NA	NA	NA	NA	7	8	7	8	8	10	10	11	9	10	7	8	9	10	9
SEAR-D	NA	NA	NA	NA	10	11	10	11	12	13	13	14	11	12	9	10	12	12	12
WPR-A	NA	NA	NA	NA	8	8	8	7	7	6	7	7	7	7	5	6	6	6	6
WPR-B	NA	NA	NA	NA	5	6	5	6	6	7	8	9	8	9	7	7	8	8	8
World	NA	NA	NA	NA	9	10	9	9	10	10	11	12	9	10	7	8	9	10	9

Table B2 Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	10	10	7	9	8	11	8	11	7	9	4	6	7	9	8
AFR-E	NA	NA	NA	NA	12	12	10	11	11	13	11	13	9	12	6	9	10	12	11
AMR-A	NA	NA	NA	NA	12	13	11	12	12	13	12	13	10	10	7	7	10	10	10
AMR-B	NA	NA	NA	NA	12	12	12	10	13	13	14	14	12	12	9	9	12	12	12
AMR-D	NA	NA	NA	NA	10	9	7	9	9	11	10	11	9	11	7	9	8	10	9
EMR-B	NA	NA	NA	NA	10	9	8	8	9	10	9	9	9	10	7	7	8	9	8
EMR-D	NA	NA	NA	NA	9	9	8	8	8	11	8	10	7	9	5	6	6	8	7
EUR-A	NA	NA	NA	NA	9	9	8	8	9	8	8	8	7	8	5	6	7	7	7
EUR-B	NA	NA	NA	NA	7	8	8	8	8	9	10	10	9	9	7	7	8	9	9
EUR-C	NA	NA	NA	NA	13	15	13	15	15	16	16	17	14	14	10	11	14	15	15
SEAR-B	NA	NA	NA	NA	7	8	7	8	8	10	10	11	9	10	7	8	9	10	9
SEAR-D	NA	NA	NA	NA	10	11	10	11	12	13	13	14	11	12	9	10	12	13	12
WPR-A	NA	NA	NA	NA	8	8	8	7	7	6	7	7	7	7	5	6	7	7	7
WPR-B	NA	NA	NA	NA	5	6	5	6	6	7	8	9	8	9	7	7	7	8	8
World	NA	NA	NA	NA	9	10	9	9	10	10	11	12	9	11	7	8	9	10	10

Table B3: Attributable fraction of DALYs (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	11	11	8	10	9	12	9	11	7	10	4	6	8	10	9
AFR-E	NA	NA	NA	NA	13	13	11	13	12	15	12	14	10	12	6	9	11	13	12
AMR-A	NA	NA	NA	NA	16	17	15	16	15	15	14	15	11	11	8	8	13	13	13
AMR-B	NA	NA	NA	NA	14	15	15	12	15	16	16	16	12	13	9	9	14	14	14
AMR-D	NA	NA	NA	NA	11	11	8	11	10	13	11	12	10	11	8	9	9	11	10
EMR-B	NA	NA	NA	NA	10	12	11	10	11	12	11	11	10	10	7	7	10	10	10
EMR-D	NA	NA	NA	NA	11	10	10	11	9	12	9	10	7	9	5	6	7	9	8
EUR-A	NA	NA	NA	NA	12	12	11	10	11	9	9	10	8	8	6	6	9	8	8
EUR-B	NA	NA	NA	NA	8	9	10	10	9	10	11	11	9	9	8	8	9	10	10
EUR-C	NA	NA	NA	NA	15	17	15	17	16	18	17	19	14	15	10	11	16	16	16
SEAR-B	NA	NA	NA	NA	9	10	10	11	11	12	12	13	10	11	8	9	10	11	11
SEAR-D	NA	NA	NA	NA	13	15	14	15	14	15	14	15	12	13	9	10	13	14	13
WPR-A	NA	NA	NA	NA	11	11	11	10	10	8	9	9	8	8	6	6	9	8	8
WPR-B	NA	NA	NA	NA	8	9	8	8	8	9	10	10	9	9	7	7	9	9	9
World	NA	NA	NA	NA	11	12	11	11	11	12	12	13	10	11	7	8	11	11	11

Table B4: Attributable mortality (000s)

d	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	0	0	1	1	1	2	1	2	0	1	4	8	11
AFR-E	NA	NA	NA	NA	0	0	1	0	1	2	1	3	1	4	1	2	6	11	17
AMR-A	NA	NA	NA	NA	0	0	0	0	1	1	1	1	2	3	3	6	7	10	17
AMR-B	NA	NA	NA	NA	0	0	1	1	2	2	3	3	4	4	2	4	13	13	26
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	1	1	0	1	2	2	4
EMR-D	NA	NA	NA	NA	0	0	0	0	1	1	2	2	2	3	1	1	6	7	13
EUR-A	NA	NA	NA	NA	0	0	0	0	1	0	2	1	4	5	4	11	12	17	29
EUR-B	NA	NA	NA	NA	0	0	0	0	1	1	3	3	4	5	2	4	11	13	25
EUR-C	NA	NA	NA	NA	0	0	1	1	5	4	12	11	12	22	5	22	36	60	96
SEAR-B	NA	NA	NA	NA	0	0	0	0	1	1	2	3	3	4	1	2	8	10	18
SEAR-D	NA	NA	NA	NA	0	0	1	1	9	6	17	17	17	20	6	8	50	52	101
WPR-A	NA	NA	NA	NA	0	0	0	0	1	0	1	0	1	1	2	3	5	5	10
WPR-B	NA	NA	NA	NA	0	0	1	1	8	5	19	13	26	28	12	22	66	69	135
World	NA	NA	NA	NA	2	1	6	4	32	26	65	59	78	101	40	87	224	280	504

Table B5: Attributable YLL (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	5	5	9	8	12	23	8	18	5	13	1	4	39	71	110
AFR-E	NA	NA	NA	NA	10	9	20	11	21	31	13	27	7	20	1	5	72	104	176
AMR-A	NA	NA	NA	NA	1	1	5	5	12	11	10	9	10	13	5	10	43	50	92
AMR-B	NA	NA	NA	NA	5	5	16	14	37	33	29	26	18	20	5	8	111	105	216
AMR-D	NA	NA	NA	NA	1	1	1	1	3	3	2	3	2	2	0	1	10	11	21
EMR-B	NA	NA	NA	NA	2	1	1	1	5	5	4	4	3	4	1	1	16	15	31
EMR-D	NA	NA	NA	NA	8	4	6	4	15	18	14	19	8	14	2	2	53	61	113
EUR-A	NA	NA	NA	NA	1	1	5	3	13	7	16	11	20	25	8	18	63	66	129
EUR-B	NA	NA	NA	NA	3	3	8	7	21	16	28	27	19	28	4	8	85	90	174
EUR-C	NA	NA	NA	NA	5	2	26	13	83	58	107	110	61	123	10	44	291	349	640
SEAR-B	NA	NA	NA	NA	4	2	6	6	17	21	21	28	14	22	2	4	64	85	148
SEAR-D	NA	NA	NA	NA	9	7	19	15	128	96	155	160	82	111	13	19	405	409	814
WPR-A	NA	NA	NA	NA	0	0	2	1	8	4	7	4	7	6	3	5	28	20	48
WPR-B	NA	NA	NA	NA	6	4	26	18	114	82	163	121	127	153	27	49	463	427	890
World	NA	NA	NA	NA	60	46	151	107	488	409	577	567	384	555	82	179	1741	1862	3603

Table B6: Attributable DALYs (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	6	7	12	11	15	30	10	21	6	15	1	4	50	88	138
AFR-E	NA	NA	NA	NA	14	12	27	16	28	42	16	33	8	22	1	6	93	131	225
AMR-A	NA	NA	NA	NA	3	3	15	14	32	24	21	17	16	21	6	13	93	92	184
AMR-B	NA	NA	NA	NA	8	8	29	24	61	51	43	36	23	25	6	8	169	151	320
AMR-D	NA	NA	NA	NA	2	2	2	2	4	5	3	3	2	3	1	1	13	15	28
EMR-B	NA	NA	NA	NA	2	2	3	3	8	8	6	6	4	5	1	1	24	24	48
EMR-D	NA	NA	NA	NA	10	5	10	7	21	25	17	23	9	16	2	3	70	78	149
EUR-A	NA	NA	NA	NA	4	3	11	8	28	14	30	20	29	37	10	22	113	104	217
EUR-B	NA	NA	NA	NA	4	4	14	10	33	25	39	37	23	33	5	9	117	118	236
EUR-C	NA	NA	NA	NA	6	3	38	21	120	87	140	148	72	147	11	48	387	454	840
SEAR-B	NA	NA	NA	NA	6	4	12	11	29	34	30	39	17	26	3	5	96	119	215
SEAR-D	NA	NA	NA	NA	14	15	40	31	174	132	189	191	91	121	14	21	522	510	1032
WPR-A	NA	NA	NA	NA	1	1	6	3	19	7	14	7	11	10	4	7	55	35	91
WPR-B	NA	NA	NA	NA	13	8	54	37	200	137	243	174	155	179	30	54	695	588	1283
World	NA	NA	NA	NA	92	75	274	198	772	619	801	755	466	660	93	201	2497	2509	5006

Key; NA, not applicable



**Appendix C: Global burden of lung cancer due to low intake of fruits and vegetables**

Table C1: Attributable fraction of mortality (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	15	14	10	13	10	14	9	12	7	10	5	7	9	12	10
AFR-E	NA	NA	NA	NA	18	18	15	17	15	17	13	16	10	13	7	10	13	16	14
AMR-A	NA	NA	NA	NA	16	16	14	16	13	14	12	13	9	10	8	8	11	11	11
AMR-B	NA	NA	NA	NA	17	18	18	13	17	17	16	17	13	13	11	10	15	15	15
AMR-D	NA	NA	NA	NA	14	14	10	13	11	15	11	13	10	12	9	10	11	13	11
EMR-B	NA	NA	NA	NA	14	13	12	12	12	13	11	11	10	11	8	8	11	11	11
EMR-D	NA	NA	NA	NA	14	13	11	12	10	14	9	11	8	10	6	6	9	11	10
EUR-A	NA	NA	NA	NA	11	11	10	9	9	9	8	8	7	7	6	6	8	8	8
EUR-B	NA	NA	NA	NA	11	12	12	12	10	11	11	12	9	10	8	8	10	11	10
EUR-C	NA	NA	NA	NA	16	18	16	18	16	18	16	18	14	14	10	12	15	16	15
SEAR-B	NA	NA	NA	NA	16	18	16	18	16	18	16	18	13	15	11	12	15	17	15
SEAR-D	NA	NA	NA	NA	16	17	16	17	16	17	16	17	13	14	10	11	15	16	15
WPR-A	NA	NA	NA	NA	12	13	12	11	10	8	8	8	8	8	6	7	8	8	8
WPR-B	NA	NA	NA	NA	12	13	12	13	12	12	13	14	11	12	10	10	12	13	12
World	NA	NA	NA	NA	14	15	13	14	13	13	13	13	10	11	8	8	11	12	12

Table C2: Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	15	14	10	13	10	14	9	12	7	10	5	7	10	13	11
AFR-E	NA	NA	NA	NA	18	18	15	17	15	17	13	16	10	13	7	10	14	16	15
AMR-A	NA	NA	NA	NA	16	16	14	16	13	14	12	13	9	10	8	8	12	13	12
AMR-B	NA	NA	NA	NA	17	18	18	13	17	17	16	17	13	13	11	10	16	16	16
AMR-D	NA	NA	NA	NA	14	14	10	13	11	15	11	13	10	12	9	10	11	14	12
EMR-B	NA	NA	NA	NA	14	13	12	12	12	13	11	11	10	11	8	8	11	12	11
EMR-D	NA	NA	NA	NA	14	13	11	12	10	14	9	11	8	10	6	6	10	12	10
EUR-A	NA	NA	NA	NA	11	11	10	9	9	9	8	8	7	7	6	6	8	8	8
EUR-B	NA	NA	NA	NA	11	12	12	12	10	11	11	12	9	10	8	8	11	11	11
EUR-C	NA	NA	NA	NA	16	18	16	18	16	18	16	18	14	14	10	12	16	17	16
SEAR-B	NA	NA	NA	NA	16	18	16	18	16	18	16	18	13	15	11	12	15	17	16
SEAR-D	NA	NA	NA	NA	16	17	16	17	16	17	16	17	13	14	10	11	15	16	15
WPR-A	NA	NA	NA	NA	12	13	12	11	10	8	8	8	8	8	6	7	8	8	8
WPR-B	NA	NA	NA	NA	12	13	12	13	12	12	13	14	11	12	10	10	12	13	12
World	NA	NA	NA	NA	14	15	13	14	13	13	13	13	10	11	8	8	12	13	12

Table C3: Attributable fraction of DALYs (%);

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	15	14	10	13	10	14	9	12	7	10	5	7	10	13	11
AFR-E	NA	NA	NA	NA	18	18	15	17	15	17	13	16	10	13	7	10	14	16	15
AMR-A	NA	NA	NA	NA	16	16	14	16	13	14	12	13	9	10	8	8	12	13	12
AMR-B	NA	NA	NA	NA	17	18	18	13	17	17	16	17	13	13	11	10	16	16	16
AMR-D	NA	NA	NA	NA	14	14	10	13	11	15	11	13	10	12	9	10	11	14	12
EMR-B	NA	NA	NA	NA	14	13	12	12	12	13	11	11	10	11	8	8	11	12	11
EMR-D	NA	NA	NA	NA	14	13	11	12	10	14	9	11	8	10	6	6	10	12	10
EUR-A	NA	NA	NA	NA	11	11	10	9	9	9	8	8	7	7	6	6	8	8	8
EUR-B	NA	NA	NA	NA	11	12	12	12	10	11	11	12	9	10	8	8	11	11	11
EUR-C	NA	NA	NA	NA	16	18	16	18	16	18	16	18	14	14	10	12	16	17	16
SEAR-B	NA	NA	NA	NA	16	18	16	18	16	18	16	18	13	15	11	12	15	17	16
SEAR-D	NA	NA	NA	NA	16	17	16	17	16	17	16	17	13	14	10	11	15	16	15
WPR-A	NA	NA	NA	NA	12	13	12	11	10	8	8	8	8	8	6	7	8	8	8
WPR-B	NA	NA	NA	NA	12	13	12	13	12	12	13	14	11	12	10	10	12	13	12
World	NA	NA	NA	NA	14	15	13	14	13	13	13	13	10	11	8	8	12	13	12

Table C4: Attributable mortality (000s)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
AFR-E	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
AMR-A	NA	NA	NA	NA	0	0	0	0	2	2	4	2	3	3	1	1	11	8	19
AMR-B	NA	NA	NA	NA	0	0	0	0	1	1	2	1	1	0	0	0	5	2	7
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
EMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EUR-A	NA	NA	NA	NA	0	0	0	0	3	1	4	1	4	1	1	1	12	4	16
EUR-B	NA	NA	NA	NA	0	0	0	0	1	0	2	0	1	0	0	0	5	1	6
EUR-C	NA	NA	NA	NA	0	0	0	0	4	1	5	1	3	1	0	0	13	3	15
SEAR-B	NA	NA	NA	NA	0	0	0	0	1	0	2	0	1	0	0	0	4	1	5
SEAR-D	NA	NA	NA	NA	0	0	1	0	4	1	6	1	3	1	1	0	15	4	19
WPR-A	NA	NA	NA	NA	0	0	0	0	0	0	1	0	1	0	1	0	3	1	5
WPR-B	NA	NA	NA	NA	0	0	1	1	6	3	11	4	8	4	2	1	27	13	41
World	NA	NA	NA	NA	0	0	4	2	25	9	37	12	27	11	7	4	100	39	139

Table C5: Attributable YLL (000s)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	3	2	2	1	1	0	0	0	6	4	10
AFR-E	NA	NA	NA	NA	0	0	2	2	6	4	4	2	1	1	0	0	14	9	23
AMR-A	NA	NA	NA	NA	0	0	6	6	35	25	31	22	17	14	3	3	93	70	163
AMR-B	NA	NA	NA	NA	1	1	6	3	21	9	15	6	6	3	1	0	50	23	73
AMR-D	NA	NA	NA	NA	0	0	0	0	1	1	0	0	0	0	0	0	2	1	3
EMR-B	NA	NA	NA	NA	0	0	1	1	4	2	3	1	1	0	0	0	9	4	13
EMR-D	NA	NA	NA	NA	1	0	3	2	6	3	4	1	1	1	0	0	15	7	22
EUR-A	NA	NA	NA	NA	0	0	7	3	38	11	34	9	19	7	3	1	100	32	132
EUR-B	NA	NA	NA	NA	1	0	6	2	21	4	20	4	6	2	0	0	54	12	66
EUR-C	NA	NA	NA	NA	1	0	10	3	53	8	50	8	15	5	1	1	130	25	155
SEAR-B	NA	NA	NA	NA	1	0	6	2	19	5	15	3	5	1	1	0	46	11	57
SEAR-D	NA	NA	NA	NA	3	2	17	7	63	19	51	13	17	4	2	0	152	45	197
WPR-A	NA	NA	NA	NA	0	0	1	1	7	3	8	3	7	2	1	1	24	10	34
WPR-B	NA	NA	NA	NA	4	4	28	20	90	51	94	43	39	21	4	3	258	142	400
World	NA	NA	NA	NA	12	9	95	51	365	146	330	117	136	61	15	9	954	394	1348

Table C6: Attributable DALYs (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	1	3	2	2	1	1	0	0	0	6	4	10
AFR-E	NA	NA	NA	NA	0	0	2	2	6	4	4	2	1	1	0	0	14	9	23
AMR-A	NA	NA	NA	NA	0	0	6	6	36	26	33	23	18	15	3	3	96	73	169
AMR-B	NA	NA	NA	NA	1	1	6	3	21	10	16	6	6	3	1	0	51	23	75
AMR-D	NA	NA	NA	NA	0	0	0	0	1	1	1	0	0	0	0	0	2	1	3
EMR-B	NA	NA	NA	NA	0	0	1	1	4	2	3	1	1	0	0	0	10	4	14
EMR-D	NA	NA	NA	NA	1	0	3	2	6	3	4	1	1	1	0	0	16	7	23
EUR-A	NA	NA	NA	NA	0	0	7	3	39	11	35	10	20	7	3	1	104	33	137
EUR-B	NA	NA	NA	NA	1	0	6	2	22	5	20	4	6	2	0	0	55	13	68
EUR-C	NA	NA	NA	NA	1	0	10	3	54	8	51	8	16	5	1	1	133	26	159
SEAR-B	NA	NA	NA	NA	1	0	6	2	19	5	15	3	5	1	1	0	47	11	58
SEAR-D	NA	NA	NA	NA	3	2	17	7	64	19	52	13	18	4	2	0	156	46	201
WPR-A	NA	NA	NA	NA	0	0	1	1	7	3	8	3	7	2	1	1	25	10	35
WPR-B	NA	NA	NA	NA	4	4	29	20	92	52	97	44	40	22	4	3	265	145	410
World	NA	NA	NA	NA	12	9	96	53	375	150	339	120	141	63	16	10	980	405	1385

Key: NA, not applicable.

**Appendix D: Global burden of stomach cancer due to low intake of fruits and vegetables**

Table D1: Attributable fraction of mortality (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	13	17	15
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	19	22	21
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	16	15	16
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	22	21	22
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	16	18	17
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	16	17	17
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	14	17	15
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	11	10	11
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	16	16	16
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	23	23	23
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	22	24	23
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	22	22	22
WPR-A	NA	NA	NA	NA	19	20	18	18	15	13	14	14	11	11	8	9	12	11	12
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	18	18	18
World	NA	NA	NA	NA	21	22	20	21	19	21	20	22	16	17	11	12	18	18	18

Table D2: Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	15	19	17
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	22	24	23
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	19	19	19
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	24	24	24
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	17	20	18
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	17	19	18
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	16	19	17
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	13	12	13
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	17	17	17
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	24	25	24
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	23	26	24
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	23	25	24
WPR-A	NA	NA	NA	NA	19	20	18	18	15	13	14	14	11	11	8	9	14	13	13
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	19	19	19
World	NA	NA	NA	NA	21	22	20	21	19	21	20	22	16	17	11	12	19	20	19



Table D3: Attributable fraction of DALYs (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	15	19	17
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	22	24	23
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	19	19	19
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	24	24	24
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	17	20	18
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	17	19	18
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	16	19	17
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	13	12	13
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	17	17	17
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	24	25	24
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	23	26	24
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	23	25	24
WPR-A	NA	NA	NA	NA	19	20	18	18	15	13	14	14	11	11	8	9	14	13	13
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	19	19	19
World	NA	NA	NA	NA	21	22	20	21	19	21	20	22	16	17	11	12	19	20	19

Table D4: Attributable mortality (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3
AFR-E	NA	NA	NA	NA	0	0	0	0	1	0	0	0	0	0	0	0	2	2	4
AMR-A	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3
AMR-B	NA	NA	NA	NA	0	0	0	0	1	1	2	1	1	1	1	1	6	3	9
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EUR-A	NA	NA	NA	NA	0	0	0	0	1	0	1	1	1	1	1	1	4	3	7
EUR-B	NA	NA	NA	NA	0	0	0	0	1	0	1	1	1	1	0	0	3	2	5
EUR-C	NA	NA	NA	NA	0	0	1	0	3	1	4	2	2	2	0	1	10	7	17
SEAR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
SEAR-D	NA	NA	NA	NA	0	0	0	0	2	1	3	1	1	1	1	1	7	5	12
WPR-A	NA	NA	NA	NA	0	0	0	0	1	0	1	0	1	1	1	1	4	2	6
WPR-B	NA	NA	NA	NA	0	0	3	3	13	6	16	8	12	9	3	4	47	29	76
World	NA	NA	NA	NA	1	1	6	5	23	12	31	16	22	17	7	8	90	58	148

Table D5: Attributable YLL (000s)

	0-4		5-14		15-29		30-44		45-59		60-69		70-79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	2	1	4	3	7	6	4	4	1	2	0	0	18	16	34
AFR-E	NA	NA	NA	NA	4	1	8	3	9	7	4	5	2	2	0	0	27	19	45
AMR-A	NA	NA	NA	NA	0	0	3	2	6	3	4	2	2	2	1	1	16	10	25
AMR-B	NA	NA	NA	NA	2	2	10	6	21	12	16	9	7	5	1	1	56	35	91
AMR-D	NA	NA	NA	NA	1	1	2	3	4	4	3	3	2	2	0	0	11	14	25
EMR-B	NA	NA	NA	NA	1	1	2	3	5	4	3	1	1	1	0	0	13	10	23
EMR-D	NA	NA	NA	NA	1	1	4	3	4	3	2	1	1	1	0	0	12	10	22
EUR-A	NA	NA	NA	NA	0	0	4	3	12	5	11	5	7	5	1	2	35	20	55
EUR-B	NA	NA	NA	NA	1	1	5	4	10	4	10	5	4	3	0	0	30	18	48
EUR-C	NA	NA	NA	NA	1	1	12	10	39	20	34	22	12	14	1	2	100	68	168
SEAR-B	NA	NA	NA	NA	0	1	1	4	5	4	4	2	1	1	0	0	12	12	25
SEAR-D	NA	NA	NA	NA	4	3	12	8	26	17	25	14	7	5	1	2	74	50	124
WPR-A	NA	NA	NA	NA	0	1	3	3	12	6	11	4	6	3	1	1	33	17	51
WPR-B	NA	NA	NA	NA	16	12	66	62	192	95	143	72	58	47	7	9	483	297	780
World	NA	NA	NA	NA	34	28	135	117	352	190	273	150	112	92	15	19	921	596	1517

Table D6: Attributable DALYs (000s)

Subregion	0-4		5-14		15-29		30-44		45-59		60-69		70-79		=80		Total		
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	2	1	4	3	7	6	4	4	1	2	0	0	19	16	35
AFR-E	NA	NA	NA	NA	4	1	8	3	9	7	4	5	2	2	0	0	27	19	46
AMR-A	NA	NA	NA	NA	0	0	3	2	6	3	4	2	2	2	1	1	16	10	26
AMR-B	NA	NA	NA	NA	2	2	10	7	21	12	16	9	7	5	1	1	58	36	94
AMR-D	NA	NA	NA	NA	1	1	2	3	4	4	3	3	2	2	0	0	12	14	26
EMR-B	NA	NA	NA	NA	1	1	2	3	6	4	3	1	1	1	0	0	14	10	23
EMR-D	NA	NA	NA	NA	2	1	4	3	4	3	2	1	1	1	0	0	12	10	22
EUR-A	NA	NA	NA	NA	0	0	4	3	12	5	11	5	7	5	1	2	36	21	58
EUR-B	NA	NA	NA	NA	1	1	5	4	11	4	10	5	4	3	0	0	31	18	49
EUR-C	NA	NA	NA	NA	1	1	13	10	40	20	35	22	12	14	1	2	102	70	173
SEAR-B	NA	NA	NA	NA	0	1	1	4	6	4	4	2	1	1	0	0	12	13	25
SEAR-D	NA	NA	NA	NA	4	3	12	8	27	18	25	15	7	5	1	2	76	51	126
WPR-A	NA	NA	NA	NA	0	1	3	3	12	6	12	4	7	3	2	1	36	19	54
WPR-B	NA	NA	NA	NA	16	13	67	63	196	97	146	74	60	48	7	9	492	303	796
World	NA	NA	NA	NA	34	28	138	119	360	194	280	154	115	94	16	19	943	610	1552

Key: NA, not applicable

**Appendix E: Global burden of colorectal cancer due to low intake of fruits and vegetables**

**Table E1: Attributable fraction of mortality (%)**

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	3	0	0	2	2	2
AFR-E	NA	NA	NA	NA	4	4	3	4	3	4	3	3	3	3	0	0	2	3	3
AMR-A	NA	NA	NA	NA	3	3	3	3	3	3	2	3	2	3	0	0	2	2	2
AMR-B	NA	NA	NA	NA	3	4	4	0	3	4	3	3	3	3	0	0	3	2	3
AMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	3	3	3	0	0	2	2	2
EMR-B	NA	NA	NA	NA	3	3	2	2	2	3	2	2	3	3	0	0	2	2	2
EMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	2	0	0	2	2	2
EUR-A	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2	2	0	0	1	1	1
EUR-B	NA	NA	NA	NA	2	2	2	3	2	2	2	2	2	2	0	0	2	2	2
EUR-C	NA	NA	NA	NA	3	4	3	4	3	4	3	4	4	4	0	0	3	3	3
SEAR-B	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	3	3
SEAR-D	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	3	3
WPR-A	NA	NA	NA	NA	2	3	2	2	2	2	2	2	2	2	0	0	1	1	1
WPR-B	NA	NA	NA	NA	3	3	3	3	2	3	3	3	3	3	0	0	2	2	2
World	NA	NA	NA	NA	3	3	3	3	3	3	2	3	2	3	0	0	2	2	2

Table E2: Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	3	0	0	2	3	2
AFR-E	NA	NA	NA	NA	4	4	3	4	3	4	3	3	3	3	0	0	3	3	3
AMR-A	NA	NA	NA	NA	3	3	3	3	3	3	2	3	2	3	0	0	2	2	2
AMR-B	NA	NA	NA	NA	3	4	4	0	3	4	3	3	3	3	0	0	3	3	3
AMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	3	3	3	0	0	2	3	2
EMR-B	NA	NA	NA	NA	3	3	2	2	2	3	2	2	3	3	0	0	2	2	2
EMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	2	0	0	2	2	2
EUR-A	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2	2	0	0	2	1	1
EUR-B	NA	NA	NA	NA	2	2	2	3	2	2	2	2	2	2	0	0	2	2	2
EUR-C	NA	NA	NA	NA	3	4	3	4	3	4	3	4	4	4	0	0	3	4	3
SEAR-B	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	4	3
SEAR-D	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	3	3
WPR-A	NA	NA	NA	NA	2	3	2	2	2	2	2	2	2	2	0	0	2	2	2
WPR-B	NA	NA	NA	NA	3	3	3	3	2	3	3	3	3	3	0	0	3	3	3
World	NA	NA	NA	NA	3	3	3	3	3	3	2	3	2	3	0	0	2	3	2

Table E3: Attributable fraction of DALYs (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	3	0	0	2	3	2
AFR-E	NA	NA	NA	NA	4	4	3	4	3	4	3	3	3	3	0	0	3	3	3
AMR-A	NA	NA	NA	NA	3	3	3	3	3	3	2	3	2	3	0	0	2	2	2
AMR-B	NA	NA	NA	NA	3	4	4	0	3	4	3	3	3	3	0	0	3	3	3
AMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	3	3	3	0	0	2	3	2
EMR-B	NA	NA	NA	NA	3	3	2	2	2	3	2	2	3	3	0	0	2	2	2
EMR-D	NA	NA	NA	NA	3	3	2	3	2	3	2	2	2	2	0	0	2	2	2
EUR-A	NA	NA	NA	NA	2	2	2	2	2	2	2	2	2	2	0	0	2	1	1
EUR-B	NA	NA	NA	NA	2	2	2	3	2	2	2	2	2	2	0	0	2	2	2
EUR-C	NA	NA	NA	NA	3	4	3	4	3	4	3	4	4	4	0	0	3	4	3
SEAR-B	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	4	3
SEAR-D	NA	NA	NA	NA	3	4	3	4	3	4	3	4	3	4	0	0	3	3	3
WPR-A	NA	NA	NA	NA	2	3	2	2	2	2	2	2	2	2	0	0	2	2	2
WPR-B	NA	NA	NA	NA	3	3	3	3	2	3	3	3	3	3	0	0	3	3	3
World	NA	NA	NA	NA	3	3	3	3	2	3	2	3	2	3	0	0	2	3	2

Table E4: Attributable mortality (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AFR-E	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AMR-A	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
AMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EUR-A	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EUR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
EUR-C	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
SEAR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
SEAR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
WPR-A	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
WPR-B	NA	NA	NA	NA	0	0	0	0	0	0	1	0	1	1	0	0	2	1	3
World	NA	NA	NA	NA	0	0	0	0	1	1	2	2	2	2	0	0	6	6	12



Table E5: Attributable YLL (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	0	0	0	0	0	0	0	0	0	2	1	3
AFR-E	NA	NA	NA	NA	1	0	1	0	1	1	0	0	0	0	0	0	3	2	5
AMR-A	NA	NA	NA	NA	0	0	1	1	2	2	2	2	1	2	0	0	6	6	12
AMR-B	NA	NA	NA	NA	0	0	1	0	1	1	1	1	1	1	0	0	4	3	7
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
EMR-D	NA	NA	NA	NA	0	0	1	0	0	0	0	0	0	0	0	0	2	1	3
EUR-A	NA	NA	NA	NA	0	0	1	1	2	2	2	2	2	2	0	0	7	6	13
EUR-B	NA	NA	NA	NA	0	0	0	0	1	1	1	1	1	1	0	0	3	2	6
EUR-C	NA	NA	NA	NA	0	0	1	1	3	3	3	3	2	3	0	0	8	10	18
SEAR-B	NA	NA	NA	NA	0	0	1	1	2	2	1	1	0	0	0	0	4	5	9
SEAR-D	NA	NA	NA	NA	1	0	2	1	2	1	2	1	1	1	0	0	6	5	11
WPR-A	NA	NA	NA	NA	0	0	0	0	1	1	1	1	1	1	0	0	3	2	5
WPR-B	NA	NA	NA	NA	1	0	3	3	6	5	4	4	2	3	0	0	17	16	34
World	NA	NA	NA	NA	4	2	12	10	21	19	18	17	11	13	0	0	67	61	128

Table E6: Attributable DALYs (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	0	0	0	0	0	0	0	0	0	2	2	3
AFR-E	NA	NA	NA	NA	1	0	1	0	1	1	0	0	0	0	0	0	3	2	5
AMR-A	NA	NA	NA	NA	0	0	1	1	3	2	2	2	2	2	0	0	8	6	14
AMR-B	NA	NA	NA	NA	0	0	1	0	1	2	1	1	1	1	0	0	4	4	8
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
EMR-D	NA	NA	NA	NA	0	0	1	0	0	0	0	0	0	0	0	0	2	1	3
EUR-A	NA	NA	NA	NA	0	0	1	1	3	2	3	2	2	2	0	0	8	7	15
EUR-B	NA	NA	NA	NA	0	0	1	0	1	1	1	1	1	1	0	0	3	3	6
EUR-C	NA	NA	NA	NA	0	0	1	1	3	3	3	4	2	3	0	0	9	11	19
SEAR-B	NA	NA	NA	NA	0	0	1	1	2	2	1	1	1	1	0	0	5	5	10
SEAR-D	NA	NA	NA	NA	1	0	2	1	2	2	2	1	1	1	0	0	7	5	12
WPR-A	NA	NA	NA	NA	0	0	0	0	1	1	1	1	1	1	0	0	4	3	6
WPR-B	NA	NA	NA	NA	1	1	4	4	6	5	5	5	3	3	0	0	18	18	36
World	NA	NA	NA	NA	5	2	13	12	24	21	20	18	12	14	0	0	74	68	142

Key: NA, not applicable

Appendix F: Global burden of oesophageal cancer due to low intake of fruits and vegetables

Table F1: Attributable fraction of mortality (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	14	18	16
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	20	22	21
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	17	16	17
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	23	21	22
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	15	19	16
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	16	17	17
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	14	16	15
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	12	11	12
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	16	16	16
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	23	22	23
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	22	24	23
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	22	22	22
WPR-A	NA	NA	NA	NA	19	*	18	18	15	13	14	14	11	11	8	9	13	11	12
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	18	19	18
World	NA	NA	NA	NA	22	24	21	22	20	21	20	22	16	18	11	12	18	19	19

Table F2: Attributable fraction of YLL (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	15	19	17
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	22	24	22
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	19	19	19
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	25	24	24
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	16	20	18
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	17	19	18
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	15	19	17
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	13	12	13
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	17	17	17
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	24	25	24
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	24	26	25
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	23	24	24
WPR-A	NA	NA	NA	NA	19	*	18	18	15	13	14	14	11	11	8	9	14	13	14
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	19	20	19
World	NA	NA	NA	NA	22	24	21	22	20	21	20	22	16	18	12	13	19	21	20

Table F3: Attributable fraction of DALYs (%)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	23	22	16	20	16	22	15	19	11	15	6	9	15	19	17
AFR-E	NA	NA	NA	NA	27	27	23	26	23	27	21	24	15	19	9	13	22	24	22
AMR-A	NA	NA	NA	NA	24	25	22	24	21	22	19	21	14	15	10	10	19	19	19
AMR-B	NA	NA	NA	NA	27	28	28	22	26	27	25	26	19	19	14	13	25	24	24
AMR-D	NA	NA	NA	NA	22	22	17	21	17	23	17	21	15	18	11	13	16	20	18
EMR-B	NA	NA	NA	NA	23	21	19	19	18	20	17	17	15	16	10	11	17	19	18
EMR-D	NA	NA	NA	NA	22	20	18	20	16	21	14	18	11	14	8	9	15	19	17
EUR-A	NA	NA	NA	NA	18	17	16	15	15	14	13	14	10	11	7	8	13	12	13
EUR-B	NA	NA	NA	NA	17	19	18	20	16	17	18	19	14	14	11	11	17	17	17
EUR-C	NA	NA	NA	NA	25	28	25	28	25	27	25	27	20	21	14	15	24	25	24
SEAR-B	NA	NA	NA	NA	25	27	25	28	24	27	25	27	19	21	14	16	24	26	25
SEAR-D	NA	NA	NA	NA	24	26	24	26	24	26	24	26	19	20	14	15	23	24	24
WPR-A	NA	NA	NA	NA	19	20	18	18	15	13	14	14	11	11	8	9	14	13	14
WPR-B	NA	NA	NA	NA	19	21	19	20	18	19	20	22	17	18	13	13	19	20	19
World	NA	NA	NA	NA	22	24	21	22	20	21	20	22	16	18	12	13	19	21	20

Table F4: Attributable mortality (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		=80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
AFR-E	NA	NA	NA	NA	0	0	0	0	1	0	1	1	0	0	0	0	3	2	4
AMR-A	NA	NA	NA	NA	0	0	0	0	1	0	1	0	1	0	0	0	2	1	3
AMR-B	NA	NA	NA	NA	0	0	0	0	1	0	1	0	0	0	0	0	2	1	3
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EMR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
EMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
EUR-A	NA	NA	NA	NA	0	0	0	0	1	0	1	0	1	0	0	0	3	1	3
EUR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
EUR-C	NA	NA	NA	NA	0	0	0	0	1	0	1	0	0	0	0	0	2	1	3
SEAR-B	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
SEAR-D	NA	NA	NA	NA	0	0	0	0	2	2	4	3	2	2	1	1	9	7	16
WPR-A	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
WPR-B	NA	NA	NA	NA	0	0	1	0	6	4	10	5	6	5	1	2	25	16	40
World	NA	NA	NA	NA	0	0	3	1	13	7	19	10	12	8	3	3	50	30	80

Table F5: Attributable YLL (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	0	2	2	1	2	0	1	0	0	5	5	10
AFR-E	NA	NA	NA	NA	2	1	8	2	15	6	7	5	2	2	0	0	35	16	52
AMR-A	NA	NA	NA	NA	0	0	2	0	9	2	6	2	2	1	0	0	20	5	24
AMR-B	NA	NA	NA	NA	0	0	3	1	11	3	7	2	2	1	0	0	24	7	31
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
EMR-B	NA	NA	NA	NA	0	0	0	1	1	2	1	1	0	0	0	0	3	4	7
EMR-D	NA	NA	NA	NA	0	1	2	2	3	4	2	2	1	1	0	0	8	9	17
EUR-A	NA	NA	NA	NA	0	0	2	0	12	2	7	2	3	2	0	0	25	6	31
EUR-B	NA	NA	NA	NA	0	0	1	1	4	1	3	1	1	1	0	0	9	4	13
EUR-C	NA	NA	NA	NA	0	0	2	0	12	2	9	2	2	2	0	0	24	6	31
SEAR-B	NA	NA	NA	NA	0	0	1	1	2	2	2	1	1	1	0	0	6	6	11
SEAR-D	NA	NA	NA	NA	2	3	11	9	30	29	37	25	9	8	1	2	89	76	166
WPR-A	NA	NA	NA	NA	0	0	0	0	4	1	4	0	2	0	0	0	10	2	12
WPR-B	NA	NA	NA	NA	3	1	32	10	90	58	86	52	32	27	3	4	246	151	397
World	NA	NA	NA	NA	9	6	64	28	196	112	172	97	59	46	6	8	506	297	802

Table F6: Attributable DALYs (000s)

	0–4		5–14		15–29		30–44		45–59		60–69		70–79		≥80		Total		
Subregion	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	All
AFR-D	NA	NA	NA	NA	0	0	1	0	2	2	1	2	0	1	0	0	5	5	10
AFR-E	NA	NA	NA	NA	2	1	8	2	16	6	7	5	2	2	0	0	36	16	52
AMR-A	NA	NA	NA	NA	0	0	2	0	9	2	6	2	3	1	0	0	20	5	25
AMR-B	NA	NA	NA	NA	0	0	3	1	12	3	7	2	2	1	0	0	24	7	32
AMR-D	NA	NA	NA	NA	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
EMR-B	NA	NA	NA	NA	0	0	0	1	1	2	1	1	0	0	0	0	3	4	7
EMR-D	NA	NA	NA	NA	0	1	2	2	3	4	2	2	1	1	0	0	8	9	18
EUR-A	NA	NA	NA	NA	0	0	2	0	12	2	8	2	3	2	0	0	26	6	32
EUR-B	NA	NA	NA	NA	0	0	1	1	4	1	3	1	1	1	0	0	9	4	13
EUR-C	NA	NA	NA	NA	0	0	2	0	12	2	9	2	2	2	0	0	25	7	31
SEAR-B	NA	NA	NA	NA	0	0	1	1	2	2	2	1	1	1	0	0	6	6	12
SEAR-D	NA	NA	NA	NA	2	3	11	9	30	30	37	25	9	8	1	2	91	78	168
WPR-A	NA	NA	NA	NA	0	0	0	0	5	1	4	0	2	0	0	0	11	2	13
WPR-B	NA	NA	NA	NA	3	1	32	10	91	59	88	53	33	27	3	4	250	154	403
World	NA	NA	NA	NA	9	6	65	28	200	114	175	99	60	47	6	8	515	302	817

Key: NA, not applicable



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